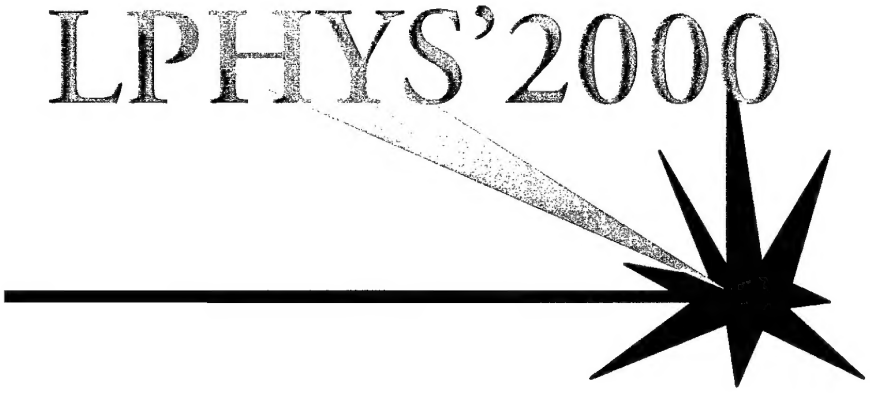
9th ANNUAL INTERNATIONAL LASER PHYSICS WORKSHOP
(LPHYS'2000)

Bordeaux, France, July 17-21, 2000

Final Report
F61775-00-WF034
CSP00-5034

BOOK of ABSTRACTS

Posters



REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	2000	Conference Proceedings

4. TITLE AND SUBTITLE

9th Int'l Workshop on Laser Physics - LPHYS 2000', Posters

5. FUNDING NUMBERS

F61775-00-WF

6. AUTHOR(S)

Conference Committee

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

General Physics Institute of the Russian Academy of Sciences
38 Vavilova str.,
Moscow 117942
Russia

8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

EOARD
PSC 802 BOX 14
FPO 09499-0200

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

CSP 00-5034

11. SUPPLEMENTARY NOTES

Two volumes: Oral Papers and Posters

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words)

The Final Proceedings for 9th Int'l Workshop on Laser Physics - LPHYS 2000', 16 July 2000 - 21 July 2000

This is an interdisciplinary conference. Topics include quantum nucleonics and short wavelength lasers, intense short pulse propagation & material interactions, strong field phenomena, physics of cold atoms, physics of lasers, and laser methods in medicine and biology.

14. SUBJECT TERMS

EOARD, Non-linear Optics, Laser cooling and atom optics, Induced gamma emission

15. NUMBER OF PAGES

200

16. PRICE CODE

N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Modern Trends In Laser Physics

Poster Session

Chair: G. Nikolaeva (Russia) and K.A. Prokhorov (Russia) — Session 1.P

1.1. S.N. Andrianov, V.V. Samartsev (Kazan, Russia)
Superradiance in V-configuration

1.2. A.I. Artemyev, M.V. Fedorov (Moscow, Russia), Yu.V. Rostovcev, M.O. Scully (Texas, USA)
Optimization of the Free Electron Laser without inversion

1.3. R.Kh. Drampyan (Ashtarak, Armenia)
Break-up of spatially modulated laser beam in a Kerr medium and formation of stimulated Raman scattering

1.4. S.V. Garnov , A.I. Ritus, S.M. Klimentov, S.M. Pimenov, V.I. Konov (Moscow, Russia)
Microwave diagnostic of non-equilibrium charge carriers in the bulk and ultra-thin layers of wide-band-gap dielectrics and semiconductors with subnanosecond time-resolution

1.5. O.K. Khasanov, A.A. Afanas'ev, R.A. Vlasov, D.M. Gorbach, and T.V. Smirnova (Minsk, Belarus)
Local field effect on optical transients in resonant media

1.6. A.V. Kir'yanov, Yu.O. Barmenkov, A.N. Starodumov (Leon, Mexico), H. Lemmetyinen (Tampere, Finland)
Application of the Z-scan technique to a saturable photorefractive medium with the overlapped ground and excited state absorption

1.7. G.D. Laptev, V.V. Volkov, E.Yu. Morozov, and A.S. Chirkin (Moscow, Russia)
Consecutive quasi-phase-matched interactions of light waves

1.8. Yu.E. Lozovik (Troitsk, Russia)
Optical properties of exciton condensate and superfluid

1.9. N.V. Maksyuta, V.I. Vysotskii (Kiev, Ukraine)
About the possibility of creation of the short-wave parametric laser on a basis of quasicharacteristic radiation generated by channeling electrons

1.10. T.G. Mitrofanova, A.A. Kalachev, V.V. Samartsev (Kazan, Russia)
Multichannel regime of optical superradiance excitation

1.11. G.Yu. Nikolaeva, K.A. Prokhorov, P.P. Pashinin (Moscow, Russia), and S.A. Gordeyev (Glasgow, UK)
Raman structural study of anisotropic polycrystalline polymers

1.12. G.Yu. Nikolaeva, K.A. Prokhorov (Moscow, Russia), R. Withnall (London, UK), S.A. Gordeyev, S.J. Shilton, and I.R. Dunkin (Glasgow, UK)
Super-selective polysulfone hollow fibre membranes for gas separation: assessment of molecular orientation by Raman spectroscopy

1.13. O. Parriaux (France), V.A. Sychugov, B.A. Usievich, K.E. Zinoviev (Russia)
Autocollimation reflection of light from the surface of corrugated multilayer structure with leaky modes

1.14. N.N. Rubtsova, S.A. Kochubei, V.L. Kurochkin, E.B. Khvorostov (Novosibirsk, Russia) and I.V. Yevseyev (Moscow, Russia)
Laser fluorescence in a dence ytterbium vapor

1.15. A.S. Shumovsky (Bilkent, Turkey)
Quantum correlation spectroscopy of Raman-active excitations

1.16. V.I. Vysotskii, S.V. Adamenko, V.A. Stratienko, N.G. Tolmachev (Kiev, Ukraine)
The method of creation of traveling inversion for x-ray laser in plasma jet by an annular pulse of femtosecond laser

1.17. S.V. Zakharov (EPPRA X-Pole, France; Troitsk, Russia)
Self-focusing or self-defocusing of an ultra-fast electron beam in a nonuniform plasma

1.18. V.A. Zuikov, A.A. Kalachev, V.V. Samartsev, A.M. Shegeda (Kazan, Russia)
Peculiarities of optical superradiance in $LaF_3:Pr^{3+}$ crystal

Superradiance in V-configuration

S.N. Andrianov, V.V. Samartsev

Lets consider ensemble of three-level atoms interacting with electromagnetic field at two transitions in V-scheme.

We shall use method of noneequilibrium statistical operator in order to solve the problem. In correspondence with it, the following dynamic variables D_m can be introduced at times much more than the time of self-correlation: operator of collective population of level α, operators of macroscopic medium polarization of $\vec{k}_\alpha$ mode at the transition 3→1, of $\vec{k}_\beta$ mode at transition 2→1, of $\vec{k}_\alpha - \vec{k}_\beta$ mode at transition 3→2.

Analysis of equations on these dynamic variables shows that superradiance in simulton regime on transitions 3→1 and 2→1 is impossible in the absence of coherence between levels 3 and 2 in the initial moment of time. Coherence between levels 3 and 2 can be realized at coherent excitation of both levels, if there is degeneracy between them, with subsequent simultaneous superradiation at transitions 3→1 and 2→1 (Hanle scheme). Coherence between levels 3 and 2 can be created also by radio-frequency pulse at the initial moment of time. Excitation can be realized via upper forth level in the last case, and coherence at transitions 3→1 and 2→1 arises spontaneously.

Solving these equations, we can get for intensity of superradiance on transitions 2→1 and 3→1

$$I_{\alpha 1} = \frac{\hbar\omega_{\alpha 1}}{8\mu\tau_c} D \sec h^2 \frac{t - t_0}{2\tau_c},$$

where $\frac{1}{\tau_c} = \frac{1}{\tau_1} D$ is the reverse selfcorrelation time, τ_1 is the time of spontaneous transition 3→1,

$$t_0 = \frac{\tau_1}{D} \ln \left| \frac{\mu N + 3\mu N_0 - 1 + D}{\mu N + 3N_0 - 1 - D} \right|$$

is superradiance delay time,

$$D = \left\{ [1 - \mu(N - N_0)]^2 - 8\mu[\mu(N - 3N_0)N_0 + N_0 - N] \right\}^{1/2}.$$

Optimization of the Free Electron Laser without Inversion

A.I. Artemyev [(*)], M.V. Fedorov[(*)], Yu.V Rostovcev[(**)], M.O. Scully[(**)]

[(*)] General Physics Institute, 38 Vavilov St., Moscow, 117942, Russia
[(**)] Texas A&M University, College Station, Texas, 77843-4242, USA

We propose a design of a free-electron laser without inversion (FELWI) [1, 2] which consists of two undulators separated by an interface region filled with a specially configured magnetic optics for the electron beam. For a broad electron energy distribution, the FELWI gain is proportional to the distribution function f(E) at the resonant energy, while the derivative f '(E) can be either positive or negative. This feature makes a FELWI advantageous when using an electron beam with a broad energy distribution.

An optimum magnetic optics configuration in the drift region, which maximizes the gain, is found. It is shown that the maximum gain can be achieved with usual magnetic optics elements – magnetic lenses and inhomogeneous turning magnets. It is shown that under the optimum conditions the gain of the considered FEL exceeds that of the originally proposed FELWI [1, 2] by the factor of 3.

[1] B. Sherman, G. Kurizki, D.E. Nikonov, M.O. Scully, "Universal Classical Mechanism of Free-Electron Lazing without Inversion", Phys. Rev. Lett., Vol. 74, N25, pp. 4605 (1995);
[2] D.E. Nikonov, M.O. Scully, G. Kurizky, "Free-Electron Laser without Inversion via Transverse Momentum Discrimination", Phys. Rev. E., Vol. 54, N 6, p. 6780 (1996).

BREAK-UP OF SPATIALLY MODULATED LASER BEAM IN A KERR MEDIUM AND FORMATION OF STIMULATED RAMAN SCATTERING

R.Kh.Drampyan

Institute for Physical Research, Armenian National Academy of Sciences
Ashtarak-2, 378410, Republic of Armenia; e-mail: rdramp@ ipr.sci.am

The generation of spatial solitons in nonlinear medium has recently become a subject of considerable interest because it opens the possibility of encoding information in the transverse structure of electromagnetic field. Transverse intensity modulation or aberration of Gaussian laser beam leads to the formation of spatial solitary waves [1,2].

In this report we present the experimental results of observation of break-up, in self-focusing Kerr medium, of spatially modulated beam having the dependence on azimuthal angle, as well as of formation of stimulated Raman scattering (SRS). In the experiment the single transverse mode laser radiation with slightly elliptical Gaussian profile at wavelength 530 nm, pulse duration 20 nsec, maximum power 10 kW and diameter 1 mm was focused into the first nitrobenzene cell with a length 25 cm. One ring with slight ellipticity surrounding the central spot was observed in the far field for laser intensity ~10^8 W/cm^2 (fig.1), as a result of spatial self-phase modulation [3]. This spatially modulated output beam from the first cell (with major and minor axes of ellipse 6 mm and 5,5 mm and diameter of inner spot 1,5 mm) was focused into the second similar nitrobenzene cell to study its break-up and generation of SRS.

Fig.1

Fig.2

Fig.3

Fig.2 shows an example of the observed transverse profile near the exit window of second cell. It consists from four concentric elliptical contours with major axis oriented at ~45^0 to the vertical direction, superimposed by number of spot in the center of ellipses, as well as by two bright spots lying on the poles of outermost ellipse. The measurements give for major and minor axes of outermost ellipse 2,5 and 2 mm, and for diameters of central and external spots 100 and 300 μm. These values are expected to be one order less inside the medium, in the focal region of focusing lens. Fig.3 shows an example of beam profile of I Stokes component of SRS generated near the threshold. Comparison of fig.2 and 3, having the same scale, shows the correlation of spatial patterns of self-focused pump and SRS beams. SRS appears in the more intense soliton-like pump beams. This experiment demonstrates the frequency conversion of bright solitons.

The formation of elliptical pattern in self-focusing beam can be caused by periodic intensity modulation of pump beam profile and propagation instabilities. The generation of the pair of solitonlike beam lying on the outermost ellipse is a result of slight ellipticity of outer ring in self-phase modulated beam profile (fig.1). The estimation of critical power density and self-focusing length for spatially modulated beam by formulae of ref. [1] gives the values $5 \cdot 10^7$ W/cm^2 and 10 cm which confirms that self-focusing conditions in the experiment were satisfied.

References:

1. A.J.Campillo, S.L.Shapiro, B.R.Suydam, Appl.Phys.Lett.**24**, 178 (1974)
2 J.W.Grantham *et al*, Phys. Rev.Lett. **66**, 1422 (1991).
3. R.Kh Drampyan, Optika i Spektroskopiya, **76**, 512, 1994;

Microwave diagnostic of non-equilibrium charge carriers in the bulk and ultra-thin layers of wide-band-gap dielectrics and semiconductors with subnanosecond time-resolution.

S.V. Garnov , A.I. Ritus, S.M. Klimentov, S.M. Pimenov, V.I. Konov

General Physics Institute of Russian Academy of Sciences, Vavilov st. 38, 117942 Moscow, Russia

phone: 095 132 81 46, fax: 095 135 02 70; e-mail: garnov@kapella.gpi.ru

ABSTRACT

Recombination times of laser-induced non-equilibrium charge carriers in natural diamond crystals, CVD diamond films, and GaAs wafers were measured with subnanosecond time-resolution applying the developed microwave-radiation technique.

The waveguide scheme was used to record the reflection and transmission of 140 GHz CW-radiation from plane-parallel specimens - Fabry-Perot resonators,- excited with IR-UV picosecond laser pulses. The measured carrier life-times in the tested specimens were found to be in the range of 1÷15 ns depending on the material and excitation conditions - surface or bulk. The most distinguished difference - by order of magnitude - between the bulk and surface recombination times was observed in GaAs.

A detailed theoretical analysis and computer simulation of microwave radiation interaction with excited specimens has been performed to validate the applicability of the applied technique.

Local field effect on optical transients in resonant media

O.K.Khasanov[1a] A.A.Afanas'ev[b] , R.A.Vlasov[b], D.M.Gorbach[c], and T.V.Smirnova[a]

[a] *Institute of Physics of Solids and Semiconductors, Academy of Sci., 17 P.Brovka str., Minsk 220072, Belarus,*

[b] *Institute of Physics, National Academy of Sciences, 70 F. Skaryna Ave., Minsk 220072, Belarus*

[c] *Belorussian State University, 4 F. Skaryna Ave., Minsk 220050, Belarus*

It is well known that in a dense resonant medium near dipole-dipole interaction can result in such effects as intrinsic optical bistability and cooperative upconversion [1]. Here we show that such an interaction has a significant effect on the propagation of laser pulses in a dense ensemble of two-level atoms and formation of spontaneous responses.

The spatio-temporal dynamics of a light pulse injected into the dense resonant medium is governed by the modified Maxwell-Bloch system. The analytical and numerical solution of this system permitted two soliton regimes to be found. The first one occurs at pulse durations much less than the both relaxation times, T_2 and T_1, which provides the coherence of the pulse-medium interaction (here $T_{1(2)}$ are the longitudinal and transversal relaxation times, respectively). This coherent soliton is distinguished from the McCall-Hann soliton mainly by its phase modulation. In addition its speed depends on near dipole-dipole interaction parameter and pulse carrier frequency detuning from resonance, and its area is less than 2π. Our results are in a good agreement with the data by [2,3]. The second regime is realized at the pulse duration being between T_1, T_2 and in the conventional sense may be regarded as the incoherent one. However, in fact, there are the conditions when the dephasing process turns out to be suppressed by the dipole-dipole interaction, and that is the point [4]. The very existence of this soliton is provided by the dipole-dipole interaction constant and frequency detuning. One-soliton solutions are found, and the division of initial pulses is revealed at the sufficiently power pulses.

The regions of soliton stability have been defined. It has been revealed that inhomogeneous broadening mechanism destabilizes the soliton formation process in a dense resonant medium when the dipole-dipole interaction is not negligible.

The influence of local field on photon echo and free induction decay phenomena has been investigated. The numerical simulation and analytical approach have shown some interesting properties of them. For example, no inhomogeneous broadening is needed for the formation of echo and echo-like signals (in both of coherent and incoherent cases). The conditions are formulated of echo generation versus the dipole-dipole interaction constant, pulse durations and influence of inhomogeneous spectral line broadening.

[1] M.P.Hehlen, H.U.Gudel et al, J.Chem.Phys. **104**, 1232 (1996).
[2] S.R.Strong, C.M.Bowden, and L.A.Allen. Opt. Commun. **67**,387 (1988).
[3] C.M.Bowden, A.Postan, and R.Inguva. J.Opt.Soc. Amer.B. **8**,1081 (1991)
[4] A.A.Afanas'ev, R.A.Vlasov, A.G.Cherstvy. ZhETF (in Russ.), **117** (2000)

[1] Corresponding author: Institute of Solid State Physics & Semiconductors, Acad. Sci of Belarus;
Tel.: (375 172)841 117; Fax: (375 172)840 888; e-mail: khasanov@ifttp.bas-net.by

A.V.Kir'yanov[1], Yu.O.Barmenkov[1], A.N.Starodumov[1]

H. Lemmetyinen[2]

[1] Centro de Investigaciones en Optica A.C., Apartado Postal 948,
Leon 37000, GTO, MEXICO
Fax: (52) 47-175000, E'mail: *kiryanov@foton.cio.mx*

[2] Institute of Materials Chemistry, University of Technology, PO Box 589,
33101 Tampere, Finland

Application of the Z-scan technique to a saturable photorefractive medium with the overlapped ground and excited state absorption

ABSTRACT

The Z-scan technique is applied to a saturable medium described by a generalized three-level scheme of photoexcitation in the conditions of overlapping spectra of the ground and excited states under the saturation conditions. Features of the approach are analysed for accurate measurements of the nonlinear refraction indices Δn_0 and n_2. It is demonstrated that corrections of the z-scan data are crucially needed to provide account for the novelties indicated. It is shown that at high probe beam intensity (i.e., at strong saturation) the difference between the calculated z-scan data on Δn_0 and n_2, basing on exploiting of the peak-to-valley $T_{p\text{-}v}$ gap only, and the real ones might be unacceptably large. Thus, to measure the nonlinear refractive indices correctly one have to use the on-axis beam intensity in the waist well-less than the saturation one, otherwise (when such measurements meet significant experimental difficulties) the proposed corrections in calculations are crucially necessary.

The model conclusions have been experimentally verified by studying z-scans for polymer films containing bacteriorhodopsin of wild-type (bR) as well as Langmuir-Blodgett films containing bR and porphyrin (PFP) for the two regimes – at comparatively weak and strong saturation. An account of the corrections proposed has allowed to get, we believe, the most explicit values for Δn_0 and n_2 indices in the sample studied.

Consecutive quasi-phase-matched interactions of light waves

G.D.Laptev, V.V.Volkov
International Laser Center, M.V.Lomonosov Moscow State University, 119899 Moscow, Russia,
phone: (095) 939 2228, fax: (095) 939 3113, e-mail: Laptev@foton.ilc.msu.su

E.Yu.Morozov and A.S.Chirkin
Physics Department, M.V.Lomonosov Moscow State University, 119899
Moscow, Russia

The number of parametric effects in a medium with second-order nonlinearity can be expended substantially owing to consecutive three-frequency interactions which can be realized only in periodically poled crystals. Quasi-phase-matched interactions make possible two consecutive in time three-frequency processes having a common wave. These processes were termed consecutive Ref.[1]. Consecutive quasi-phase-matched (CQPM) interactions of light waves with frequencies ω, 2ω, 3ω and ω, 2ω, 4ω have been considered in Ref.[2-4].

In contrast to cascade frequency conversion in crystals located one another or in several nonlinear gratings in the same crystal the interaction in CQPM conversion occurs on different orders of the same nonlinear grating.

In the present paper, attention is devoted primarily to the special features of energy exchange in CQPM interactions of waves with frequencies ω, 2ω, 3ω and ω, 2ω, 4ω. These features are associated with the fact that the Manley-Row relations are inapplicable to these processes and the energy of the pump wave with frequency ω can be almost completely converted to the energy of one of the two waves with frequency $1/4\omega$, $1/3\omega$, $2/3\omega$ ω, $3/2\omega$, 2ω, 3ω, or 4ω. For example, dependencies of the weave intensities on propagation distance for processes $\omega + \omega = 2\omega$ and $2\omega+\omega = 3\omega$ (see Fig.1) are presented below.

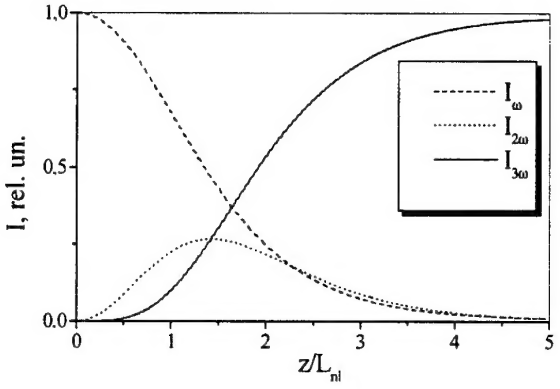


Fig.1.

We consider in more detail the methods used to analyze the CQPM three-frequency interactions in a case of co- and counterpropagating light waves. Attention is devote primarily to finding conditions for realization high efficiency CQPM processes in a periodically poled lithium niobate.

1. S.A.Akhmanov, R.V.Khokhlov, *Problems of Nonlinear Optics,* Gordon and Breach, New York, 1972.
2. A.S.Chirkin, V.V.Volkov, *J. Russian Laser Research*, 19, 409, 1998.
3. V.V.Volkov, G.D.Laptev, et al., *Quantum Electronics*, 28, 1020, 1998.
4. V.V.Volkov, A.S.Chikin, *Quantum Electronics*, 28, 95, 1998.

Optical properties of exciton condensate and superfluid

Yurii E.Lozovik

Institute of Spectroscopy, Russian Academy of Sciences Moscow region, Troitsk 142092 Russia;
e-mail: lozovik@isan.troitsk.ru ; Fax:+7 095 334 08 81

Phase diagram, Bose condensation, supefluidity and optical properties of exciton system are studied. Especially excitonic system in coupled quantum wells (CQW) or quantum dots (QD) which now are under intensive experimental investigations are analized.

Influence of the normal and parallel magnetic field on condensation, superfluidity and optical properties of excitons in CQW is analyzed. In-plane magnetic field is found to change drastically photoluminescence kinetics of interwell excitons. The effect is due to the in-plane magnetic field induced displacement of the indirect exciton dispersion in a momentum space. In-plane magnetic field is, therefore, an effective tool for the exciton dispersion engineering. Josephson phenomena are studied for CQW and QD.

Stimulated two-photon emission by Bose-condensed excitons accompanied by a coherent two-exciton recombination, i.e., by simultaneous recombination of two excitons with opposite momenta is investigated.

Raman light scattering accompanied by a similar two-exciton recombination (or generation of two excitons) is also analyzed. The processes under consideration can occur only if a system contains Bose condensate, therefore, their detection can be used as a new method to reveal Bose condensation of excitons. Moreover it gives unique possibility for direct study of nondiagonal order (anomalous mean).

Influence of random field of impurities, surface roughness on optical properties and superfluidity is analized.

ABOUT THE POSSIBILITY OF CREATION OF THE SHORT-WAVE PARAMETRIC LASER ON A BASIS OF QUASICHARACTERISTIC RADIATION GENERATED BY CHANNELING ELECTRONS

N.V.Maksyuta, V.I.Vysotskii

Kiev Shevchenko University, Radiophysical Faculty, 01033, Vladimirskaya St. 64, Kiev, Ukraine; E-mail: maksyuta@mail.univ.kiev.ua

The paper considers the problem of the creation of laser-type radiation sources on the basis of three-frequency nonlinear parametric amplification on the system of relativistic channeling charged particles in domain structures (for example in segnetoelectrics or ferromagnetics). In fact such a problem is a natural merging of tree processes of radiational physics channeling phenomenon with a corresponding formation of quantum levels resonance system, laser parametric three-wave amplification in a linear disperse environment and FEL - system in a periodic structure. The advantage of such an approach is in a possibility of simultaneous realization of:

a) resonance properties of non-linear receptivity in channeling particles system;
b) the possibility of inverse amplification to the pumping at the expense of linear crystal environment dispersion;
c) superintensive pumping by resonance periodic field of the domain structure.

Considering a process in a moving particle coordinate system we see that a wave pumping frequency (static electric or magnetic domain structure field transformed into a field of moving wave serves as a pumping wave) and a transition frequency $\omega_3 = (E_3 - E_1)/h$ (of three-level system) coincidence leads to a parametric amplification of a short-wave radiation with $\omega = \omega_2/[1 - \beta(n(\omega))]$ frequency (fulfilling Doppler formula where $\omega_2 = (E_2 - E_1)/h$, $\beta = v/c$. It becomes possible at phase synchronism condition fulfillment $\omega_1 n(\omega_1)/c = \omega_2 n(\omega_2)/c + \omega_3 n(\omega_3)/c$ which can be realized in the regime of inverse parametric pumping $\omega_1 = (E_3 - E_2)/h$ is a free-wave frequency). We have as well other requirements analyzed in the paper in detail.

MULTICHANNEL REGIME OF OPTICAL SUPERRADIANCE EXCITATION

T.G.Mitrofanova, A.A.Kalachev, V.V.Samartsev

Kazan Physical and Technical Institute of RAS

10/7 Sibirsky Trakt Str., Kazan, 420029, Tatarstan, Russia

phone: (8432)763681; fax: (8432)765075; e-mail: samartsev@dionis.kfti.kcn.ru

The multichannel regime of the excitation of optical superradiance in both two- and multilevel systems is investigated in details. It is demonstrated that this regime is the generalization of the triggering regime of superradiant excitation. We derive kinetic equation governing the dynamics of polarization waves and the population grating in a system of excited particles interacting with each other through the common field of emitted photons. The results of numerical simulation in various schemes of multipulse excitation of superradiance are presented. It is shown that superradiant signals may be emitted in the few different space channels. The possibility of associative readout of information under the multichannel regime of long-lived superradiance is discussed.

Raman structural study of anisotropic polycrystalline polymers

G.Yu. Nikolaeva, K.A. Prokhorov, P.P. Pashinin, and S.A. Gordeyev*

Institute of General Physics, Russian Academy of Sciences,
38 Vavilova St., 117942 Moscow, Russia. E-mail: cyrpro@gpi.ru

**Department of Chemical and Process Engineering, University of Strathclyde, James Weir Building, 75 Montrose Street, Glasgow G1 IXJ, Scotland, UK*

ABSTRACT

A new experimental method for the structural study of the oriented polycrystalline polymers by Raman spectroscopy is proposed. The method is based on decomposition the Raman band around 1300 cm^{-1} assigned to CH_2- twisting vibrations into two separate lines. This decomposed lines are associated with polymer chains of crystalline and amorphous regions. The measurement of integral intensities of the decomposed lines allows to determine crystallinity of the polymer. It implies that the orientation parameters of the macromolecule distribution function can be calculated separately for both crystalline and amorphous regions and that strict relationships exist between parameters of the distribution function and the depolarization ratios of Raman lines. These ratios could be easily measured on practice.

The structural changes upon draw have been studied by this method in the ultra high molecular weight polyethylene. It was shown that valuable information about the efficiency of fibrillar structure formation could be obtained too.

This work was supported by the Russian Foundation for Basic Research
(project code 99-02-17876).

Super-selective polysulfone hollow fibre membranes for gas separation: assessment of molecular orientation by Raman spectroscopy

G.Yu. Nikolaeva[1], K.A. Prokhorov[1], R. Withnall[2], S.A.Gordeyev[3], S.J. Shilton[3], and I.R. Dunkin[4]

[1]*General Physics Institute, Russian Academy of Sciences, Vavilov St., 38, 117942 Moscow, Russia, E-mail: cyrpro@kapella.gpi.ru*
[2]*School of Chemical and Life Sciences, University of Greenwich, London, UK*
[3]*Department Chemical & Process Engineering, University of Strathclyde, Glasgow, UK*
[4]*Department of Pure and Applied Chemistry, University of Strathclyde, Glasgow, UK*

Over the last 10 years, gas separation by asymmetric polymeric membranes has become an economically viable technology. Advanced polymer solutions now enable effective membranes to be spun as hollow fibres. The performance of asymmetric gas separation membranes is dependent on a thin active layer. It has been acknowledged that molecular orientation in the active layer will be affect membrane selectivity.

Spectroscopic techniques are widely used to measure orientation of polymer molecules in fibres. However, to the best of our knowledge, the direct measurement of molecular orientation in asymmetric membranes and correlation with primary fabrication conditions and performance has only recently been carried out using plane-polarised reflectance infrared spectroscopy. In this work we have shown that polarised Raman spectroscopy is even more advanced technique and quantitative estimates of molecular orientation in the active layer of polysulfone membranes can be obtained.

Asymmetric polysulfone hollow fibre membranes for this study were spun using a dry/wet spinning process. Fibres were spun at low- and high dope extrusion rates and hence at different levels of shear. The selectivity of the high-shear membranes were heightened and even surpassed the recognised intrinsic selectivity of the membrane polymers. Using an approach based on measurements of depolarisation ratios of Raman-active vibrations we have found analytical relations between orientation parameters of macromolecules and depolarisation ratios of the line in Raman spectrum of polysulfone related to the in-plane vibration of the benzene ring. It has been shown that the orientation parameters measured in the high-shear membranes are higher than these of isotropic and low-shear samples. The results confirm the fact, revealed previously by IR spectroscopy, that spinning of membrane fibres at high shear rates may induce anisotropy on the molecular level in the active layer.

This work was supported by the Russian Foundation for Basic Research (project code 99-02-17876).

Autocollimation reflection of light from the surface of corrugated multilayer structure with leaky modes

O.Parriaux, V.A.Sychugov, B.A.Usievich, K.E.Zinoviev

It is well known that multilayer dielectric or metal-dielectric gratings have some guiding properties (light can propagate along the layers). However, till the present moment the role of guiding in the process of grating functioning was not clarified. In this report we tried to show the major role that leaky modes in the multilayer structure play in the effective work of grating. In particular, we have shown that high diffraction efficiency of the grating in the Littrow mounting is a result of excitation of the waveguide (leaky) modes by incident light beam.

In report three types of grating structures have been considered: 1) corrugated waveguide layer on top of multilayer dielectric mirror; 2) multilayer dielectric mirror on the corrugated substrate (that is fully corrugated structure); 3) intermediate structure. Comparison of working characteristics of these structures in the Littrow mounting has been performed

Laser fluorescence in a dense ytterbium vapor

N.N.Rubtsova, V.N.Ishchenko, S.A.Kochubei, V.L.Kurochkin, E.B.Khvorostov, I.V.Yevseyev

Fluorescence of ytterbium vapor excited by dye laser radiation at the intercombination Yb transition $6s6p\ ^3P_1$ - $6s^2\ ^1S_0$ is investigated in a range of 300 - 500 °C of the sample cell temperatures.

At low temperatures, the optically thin samples revealed one-exponential kinetics of resonant fluorescence decay with lifetime 880 ns, in agreement with this value for radiative decay of $6s6p\ ^3P_1$ level. In this region of densities, the polarisation degree of fluorescence was easured versus buffer gas pressure for depolarizing collisions investigations. The increase of Yb ensity leads to non-exponential fluorescence decay, which may be attributed both to the radiation trapping and the influence of the neighboring metastable levels.

Further increase of Yb temperatures and densities in the presense of Xe changes cruciahy the shape of kinetic curve, leads to the increase of short-wavelength comportent of fluorescence and changes the polarisation degree of fluorescence. Various mechanisms (the contribution of collective coherent processes, the formation of excimer compounds) are considered to explain specific features of this kinetics. Possible applications are under consideration.

Financial support of RFBR grants # 97-02-18496 and # 98-02-16390 and Science Ministry grant "L,aser Physics" is acknowledged.

QUANTUM CORRELATION SPECTROSCOPY OF RAMAN-ACTIVE EXCITATIONS

Alexander S. Shumovsky

Physics Department, Bilkent University, Bilkent, 06533 Ankara, Turkey
e-mail: shumo@fen.bilkent.edu.tr

A new method of measurement of quantum statistical properties such as the number variance (the width of probability distribution to have a given number of quanta) of the Raman-active excitations [1] is discussed. A general fundamental relation connecting the correlation of Stokes and anti-Stokes modes to the number variances of vibration and pump modes in the Raman-active materials is derived. It is shown that under certain conditions this relation can be used to determine the thermal equilibrium number variance of Raman-active excitations. These conditions include the coherent pump. Time and temperature ranges for which the conditions can be satisfied are studied and found to be able in today's experimental standards. The most important condition is related to the duration of pumping pulse, which is estimated to be of the order of $3 \div 10$ fs. The result is valid in the presence of multimode pump as well as for the coupling of pump to many vibration modes.

As a particular example of common interest, the phonon squeezing due to the polariton mechanism [2,3] in an ionic crystal is considered. Another example is provided by the phonon squeezing in GaAs/AlAs superlatices where the phonon is involved in the associated indirect transition [4].

---

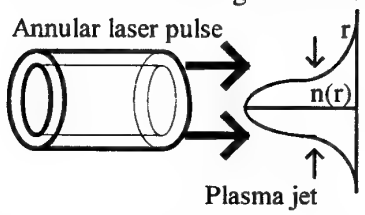
1. O.E. Mustecaplioglu and A.S. Shumovsky, *Phys. Rev. B* 60, 3970 (1999)
2. A.V. Chizhov, R.G. Nazmitdinov and A.S. Shumovsky, *Quantum Optics* 3, 1 (1991)
3. A.S. Shumovsky, in: *Modern Nonlinear Optics*, edited by M. Evans and S. Kielich (Wiley, New York, 1993), p. 375
4. O.E. Mustecaplioglu and Shumovsky, *Appl. Phys. Lett.* 70, 3489 (1997)

THE METHOD OF CREATION OF TRAVELING INVERSION FOR X-RAY LASER IN PLASMA JET BY AN ANNULAR PULSE OF FEMTASECOND LASER

V.I. Vysotskii*+, S.V. Adamenko+, V.A. Stratienko+, N.G. Tolmachev+
+Laboratory of Electrodynamical Investigation, Concern "ENRAN', Kiev, Ukraine
*Kiev Shevchenko University, Radiophysical Faculty, 252033, Kiev, Ukraine

The problem of generation of a superdense tubular squeezing electron beam with density about $j \approx 10^{11}$ A/cm^2 for creation of X-ray laser traveling inversion by the use of an annular powerful femtosecond laser pulse is studied. The result of the longitudinal action of the ponderomotive force of annular laser pulse (outer radius R_0, thickness $\delta R << R_0$, electron-laser pulse interaction energy $W(r) = (\pi e^2/mc\omega^2)J_0(r)$) on a slow gas (plasma) jet coaxial with this pulse and having a radial density $n(r) = n_0 \exp(-r^2/r_0^2)$ is occurs a radial acceleration of electrons to the center of the beam. The total energy of every of electrons accelerated by the laser pulse in the region $r \le R_0$ is $W(r) = [(\pi e^2/mc\omega^2)\, J_0 - 4\pi R_0 \delta R\, n(R_0) e^2\, ln\, (R_0/r)]$.

For the case of action of a laser pulse with an intensity $J_0 = 10^{18}$ W/cm^2, frequency $\omega = 2\cdot 10^{15}$ s^{-1} and focal dimensions $R_0 = 5$ μm, $\delta R = 1$ μm on a plasma jet with an effective radius $r_0 = 2.3$ μm and maximum density on the axis $n_0 = 10^{20}$ cm^{-3} the energy of every of electrons accelerated by the laser in a region with a radius R_1 (here $R_0 > R_1 > R_0/10^3$) is $W(R_1) \approx 10$ keV. Accelerated electrons leave the region of action of the annular laser pulse in time $\Delta t \approx m\, \omega\, \delta R\, (2c\pi e^2 J_0)^{1/2} \approx 3\cdot 10^{-14}$ s, which is several orders of magnitude less than the duration of the laser pulse. The motion of the tubular current converging towards the center increases the volumetric density of moving electrons from the initial value $n_e(R_0) \equiv n(R_0)$ to $n_e(R) \equiv n(R_0)R_0/R$ on a ring of radius R. The main mechanism of braking of the converging current of electrons, characterized by velocity v(R) and density $j(R) = ev(R)n_e(R)$, at interaction with the plasma target is a collective interaction (two-beam kinetic plasma instability), characterized by the development increment $\delta\omega \approx \omega_p[n_e(R)/n(R)]$. Here $\omega_p = [4\pi\, n(R)e^2/m]^{1/2}$ is the plasma frequency of the jet. The condition of "triggering" of such a collective interaction mechanism is $n_e(R) \le n(R)$. With account of the relation n(r), the radius R_1 of the beginning of an effective collective braking of electrons accelerated by the laser is equal to $R_1 \approx R_0 \exp[-R_0^2/r_0^2]$. The length of the full braking path of accelerated electrons in the plasma target is equal to $L \approx v(R_1)\delta\omega \approx v(R_1)/\omega_p(R_1)$. When the condition $L < 2R_1$ is met, all the accelerated electrons will be braked within the volume of a plasma filament of a radius R. The braking time δt is equal to $1/\delta\omega$. Such a braking will raise the temperature of the filament to



$$KT \approx R_0 \delta R\, n(R_0)\, W(R_1) / \{ \int_0^{R_1} n(r) r dr + R_0 \delta R\, n(R_0) \}.$$

At the above-presented parameters of the laser pulse and characteristics of the plasma target, we have $R_1 \approx 0.05$ μm; $\omega_p(R_1) \approx 5\cdot 10^{14}$ s^{-1}; and $L \approx 0.1$ μm. The density of current and intensity of accelerated electrons beam on the surface of a region of a radius R_1 are $j \approx n_0 v(R_1) \approx 10^{11}$ A/cm^2 and $J = 10^{15}$ W/cm^2. The resulting temperature of the central region of the plasma jet of a radius R, corresponding to these values is $KT \approx 5$ keV. At such a temperature (after an adiabatic cooling of the plasma filament) there are met threshold conditions of the triggering of a X-ray laser with a generation wave length right down to the minimal value of $\lambda_x \approx 0.3$ nm, based on transitions between inner electronic shells of atoms with $Z \le 30$.

Self-focusing or self-defocusing of an ultra-fast electron beam in a nonuniform plasma

S.V. Zakharov

EPPRA X-Pole, Ecole Polytechnique, France
TRINITI, Russia

A study is made of the nonlinear behavior of a relativistic electron beam in a nonuniform electric and magnetic fields which arise in a nonuniform plasma when the charge of the beam is partially neutralized in low density plasma $n_b > n_e$. If plasma density increases in the forward direction of a beam propagation self-focusing of the beam realizes and self-defocusing - otherwise.

Relativistic electrons generated in laser-plasma interaction or injected into plasma by some special source produce self-consistent electric and magnetic fields. If there is some preferential direction i.e. axis for generated electrons the electromagnetic fields forms like a channel for the beam propagation. The beam particles execute betatron oscillations in the azimuthal magnetic and radial electric fields.

In an electromagnetic field which is nonuniform along the beam or which varies with time, the Poincare invariant $\oint pdq$ is conserved during such oscillations. Using the relations $q_\perp \propto a$ and $p_\perp \propto \sqrt{\gamma\beta m_e e a (B_\varphi - E_r/\beta)}$ [a is the amplitude of the betatron oscillations of the beam particles in the fields B_φ and E_r; $\beta = \frac{\sqrt{\gamma^2 - 1}}{\gamma}$; γ is the relativistic factor], we fined the estimate $\oint pdq \propto \sqrt{\gamma\beta m_e e a^3 (B_\varphi - E_r/\beta)} = const$ from which we see that as the magnetic field increases, or the electric field decreases, along the paths of the particles the amplitudes of the betatron oscillations decrease, the beam becomes focused and otherwise the beam becomes defocused.

In the report we will discuss the physical phenomena in a plasma i.e. an increase or decrease in the charge neutralization of a beam in a plasma with increasing or decreasing density cause self-focusing or self-defocusing of ultra-fast electron beams.

The equilibrium state of a relativistic electron beam in a plasma is attained at a plasma ion density $n_i \geq n^* = \frac{n_b}{Z_i \gamma^2}$ (if $n_i < n^*$, the repulsive electrostatic forces are stronger than the Loretz force, and there is no equilibrium), Z_i is a mean charge of plasma ions. If the ion density increases along the beam from the level n^* to n_b/Z_i the plasma electrons leave the beam channel, the ions partially neutralize the beam space charge and the electron beam should be focused.

The maximum possible degree of focusing is $\frac{n_{b\,max}}{n_{b\,initial}} = \gamma^2$.

EPPRA X-Pole, Ecole Polytechnique, 91128 Palaiseau, France
Phone: +33 1.69.33.32.45, Fax: +33 1.69.33.30.23
E-mail: zakharov@eppra.polytechnique.fr

PECULIARITIES OF OPTICAL SUPERRADIANCE IN $LaF_3:Pr^{3+}$ CRYSTAL

A.A.Kalachev, V.V.Samartsev, V.A.Zuikov, A.M.Shegeda

Kazan Physical and Technical Institute of RAS

10/7 Sibirsky Trakt Str., Kazan, 420029, Tatarstan, Russia

phone: (8432)763681; fax: (8432)765075; e-mail: samartsev@dionis.kfti.kcn.ru

The specific features of optical superradiance formation in $LaF_3:Pr^{3+}$ crystal are investigated both theoretically and experimentally. Spatial, polarization and temporal peculiarities of superradiant signals observed in this crystal are analyzed. The results of numerical simulation of superradiance process taking into account high inversion density and hyperfine structure of electron levels of praseodymium ions in LaF_3 crystal matrix are presented. Various schemes of superradiance excitation realizable in multilevel system of $LaF_3:Pr^{3+}$ crystal are discussed in details.

Strong Field Phenomena

Poster Session

Chair: M.V. Fedorov (Russia) **Session 2.P**

2.1. P.G. Alcheyev, V.E. Chernov, B.A. Zon (Voronezh, Russia)
Laser-induced internuclear separation in H-ion

2.2. A.V. Andreev, A.B. Kozlov (Moscow, Russia)
Light-induced anisotropy of atomic response in superstrong spatially inhomogeneous field

2.3. I.I. Bondar and V.V. Suran (Uzhgorod, Ukraine)
Induced by ac–Stark effect nonresonant mixing of metastable levels of Ba atoms

2.4. O.I. Denisenko and S.P. Roshchupkin (Sumy, Ukraine)
Compton effect in the presence of two strong light waves

2.5. M. Fofanov (Moscow, Russia)
Scattering of relativistic electrons in a head-on collision with a focused laser pulse

2.6. Ph. Hering and C. Cornaggia (Gif-sur-Yvette, France)
Non-sequential double ionization of small molecules induced by a femtosecond laser field

2.7. V.A. Kovarsky, O.B. Prepelitsa (Kishinev, Moldova)
Multiphoton resonance processes in dipole molecules in the presence of polar medium fluctuations

2.8. N.L. Manakov, B. Borca, A.V. Flegel, M.V. Frolov and A.F. Starace (Voronezh, Russia; Lincoln, NE, USA)
Quasistationary quasienergy state theory of harmonic generation

2.9. A.N. Naumov, A.M. Zheltikov, A.B. Fedotov, D.A. Sidorov-Biryukov, A.P. Tarasevitch, Ping Zhou, and D. Von der Linde (Moscow, Russia)
Ionization effects in high-order harmonic generation in gas-filled hollow fibers

2.10. H. Nieto (Peru)
Quantum effects without quantum fields in Compton-like process

2.11. A.I. Pegarkov, E. Charron and A Suzor-Weiner (Paris, France)
Direct and sequential double ionization of molecules by strong laser pulses

2.12. O. Petrova and G. Ferrante (Palermo, Italy)
Test of Bi-maxwellianity on numerical distribution functions of laser-embedded plasma

2.13. V.T. Platonenko, V.V. Strelkov (Moscow, Russia)
Off-axial phase-matched high-order harmonic generation in extended medium under self-channeling of laser beam

2.14. S.V. Popruzhenko (Moscow, Russia)
High harmonic generation in an atomic jet and a hollow-core fiber

2.15. S.V. Popruzhenko (Moscow, Russia)
Distribution in the net electron momentum for double ionization

2.16. R.M. Potvliege (Durham, UK)
Disappearance of the dressed bound states in photodetachment from a short range potential by an intense high-frequency laser field

2.17. L. Quaglia and C. Cornaggia (Gif-sur-Yvette, France)
Excited multi-charged atomic fragments coming from laser-induced Coulomb explosion of molecules

2.18. H.R. Reiss (Washington, DC, USA)
Connection between the strong field approximation (SFA) and the high frequency approximation (HFA)

2.19. S.P. Roshchupkin (Sumy, Ukraine)
Interference effects in the strong field of two light waves

2.20. S.P. Roshchupkin and O.B. Lusenko (Sumy, Ukraine)
Spectrum of bremsstrahlung by an electron scattered by a nucleus in the field of two strong light waves

2.21. N.Yu. Shubin and V.D. Taranukhin (Moscow, Russia)
Relativistic modification of high-order harmonic spectra generated by multicharged ions: effects of plateau drop and cut-off suppression

2.22. O.V. Smirnova (Moscow, Russia)
On the applicability of the Kramers-Henneberger approximation

2.23. M.B. Smirnov and V.P. Krainov (Moscow, Russia)
The evolution of large clusters in a super-intense laser field

2.24. M.E. Sukharev (Moscow, Russia)
The excitation of vibrational states of the H_2^+ at the tunneling ionization of the H_2 by a strong laser field

2.25. V.V. Suran and I.I. Bondar (Uzhgorod, Ukraine)
Stimulated hyper-Raman scattering effect at influence of laser radiation on Ba atoms

2.26. V.D. Taranukhin (Moscow, Russia)
Atom above-threshold ionization with two-component field: applications for high-order harmonic generation with frequency selection and for femtosecond streak camera

2.27. F.A. Weihe et al. (Palaiseau, France)
Ultrafast-pulse metrology as a probe of femtosecond plasma dynamics

2.28. G.L. Yudin and M.Yu. Ivanov (Ottawa, Canada)
Physics of correlated double ionization of Helium in strong laser fields

2.29. M. Zarkone, D. Persano Adorno, G. Ferrante (Palermo, Italy)
High order harmonic generation efficiency in n-type silicon and InP

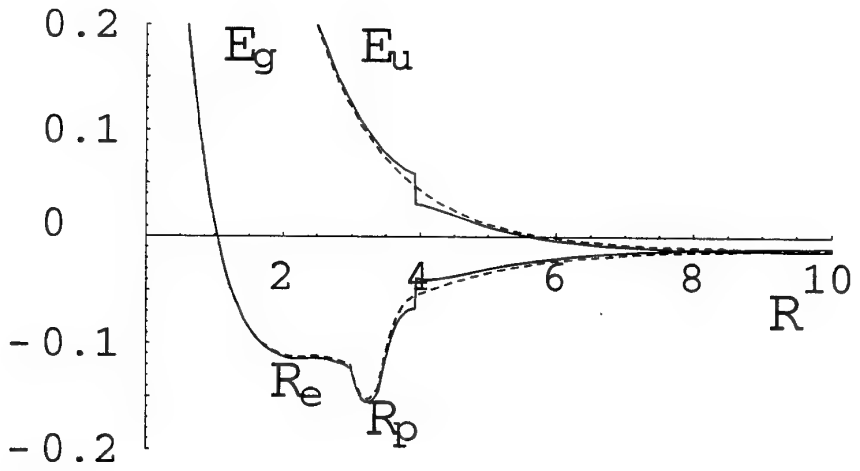
Laser-induced internuclear separation in H_2^+

P. G. Alcheyev, V. E. Chernov, B. A. Zon
Voronezh State University, Russia, *e-mail: zon@niif.vsu.ru*

We mention a possibility for new internuclear separation to arise in neutral molecules or molecular ions under laser field. This new internuclear separation is not connected with the internuclear separation R_e in absence of the laser field, but it is due to a possible maximum of the electronic polarizability of the molecule or its ion at some internuclear distance R_p. Obviously, it is R_p that determines new equilibrium distance when the laser field is sufficiently high. For well-studied H_2^+ molecular ion our calculation gives $R_p \simeq 3.5$ a. u.

To describe the effect of the above mentioned shift of the internuclear distance, we construct an effective potential for the nuclei motion in laser field and consider this motion in terms of classical mechanics.

The static polarizability $\alpha(R, \omega = 0)$ satisfactorily describes molecule interaction with laser radiation for nonresonant frequences ω and for relatively low amplitudes F of the laser field. However, the resonance of the ground $1s\sigma_g$ and the first excited $1s\sigma_u$ electronic term is possible for ω almost in any range since these two non-perturbed terms converge to the same value at infinity: $E_{0g}(R = \infty) = E_{0u}(R = \infty)$. Since the perturbative approach fails in resonant case, we propose a simple way to take into account this resonance by a combination of perturbative and two-level approaches. The calculated H_2^+ molecular terms in the field are shown on the picture for $\omega = 0.1$ a. u. and $F = 0.1$ a. u.. The dashed line shows the calculation without the account for the resonance. The account for the resonant perturbation without the non-resonant polarizability was performed, *e. g.*, in [1].



[1] E. A. Aubanel, J.-M. Gauthier and A. D. Bandrauk / Phys. Rev. A **48**, 2145 (1993)

Light-induced anisotropy of atomic response in superstrong spatially inhomogeneous field

A.V.Andreev, A.B.Kozlov
Physics Department, M.V.Lomonosov Moscow State University,
Moscow 119899 Russia
E-mail: andreev@sr1.ilc.msu.su
Fax: (095)939-3113, Phone: (095)939-3092

The nonlinear response of an atom interacting with the strong electromagnetic field is quite different in the case of plane wave or laser beam. This is due to the fact that the symmetry properties of an atom interacting with the plane wave differs from that for the spatially inhomogeneous electromagnetic field. As a result such effects as a "forbidden" second harmonic generation, induction of nonoscillating dipole moment, etc become allowed and possible.
Here we report the results of the study on the nonlinear response of an atomic medium interacting with the spatially inhomogeneous field produced by the interference of the two plane waves with the same frequencies and different wave vectors. There are changes both in the nonlinear response of an individual atom or extended medium. The response of individual atom depends on its position in the interference field (node, antinode or intermediate plane), and the most drastic change occurs when atom is placed in the plane of the highest gradient. The atomic response depends also on the intensity and polarization of the incident pulses. We discuss the results of the computer simulation on the atomic response in the superstrong spatially inhomogeneous laser field and explain the main mechanisms responsible for its unusual intensity and polarization properties.
The specificity of the response of an extended medium is primarily due to the translation properties of the whole system including homogeneous medium and interference field. It is evident that the nonlinear response of such a system should reflect its periodicity. This periodicity results in the specific phase-matching conditions and determines the frequency- angular spectrum of response.

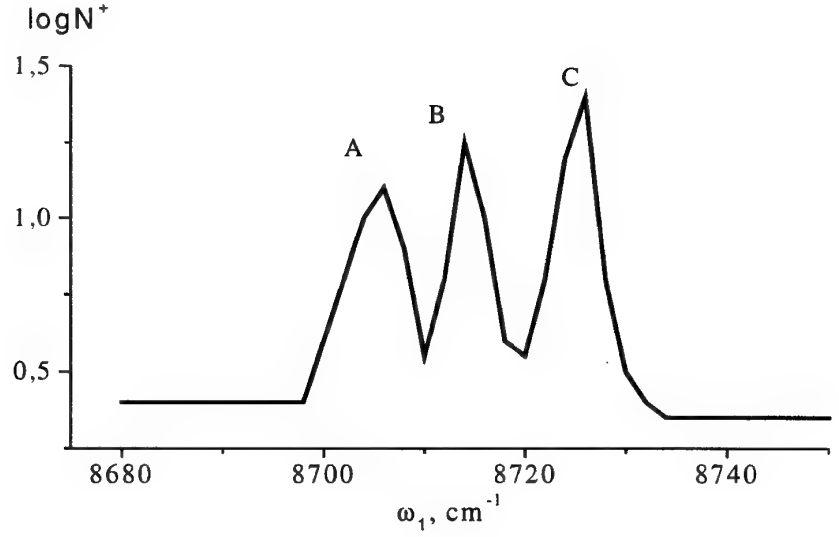
The developed microscopic theory of an atom interaction with superstrong spatially inhomogeneous fields enables us to predict the new non-local interaction effects and unify them with previously known effects occurring when atom interacts with the plane waves. It is open up the new opportunities in the development new methods of the controllable ultrashort laser pulse action on the gases, solids and plasmas.

INDUCED BY AC–STARK EFFECT NONRESONANT MIXING OF METASTABLE LEVELS OF Ba ATOMS

I.I.Bondar, V.V.Suran
Physical Department, Uzhgorod State University,Voloshin str.54, 294000 Uzhgorod, Ukraine
Tel.(+38 03122) 361-87, Fax.(+38 03122) 323-39, e-mail: bondar@univ.uzhgorod.ua.

The investigation of perturbation of Ba atoms under circumstances when shift of energy levels is comparable with difference between energies of levels was performed. In particular, the perturbation of 6s5d $^3D_1$ and 6s5d $^3D_2$ states by radiation of laser on colour centres (CCL) with frequency ω_1~8700 cm^{-1} was investigated. Perturbation of these levels by such radiation was strong as the frequency of this radiation is close to frequencies ω_{mn}, corresponding to transitions from mentioned above states to 6s6p $^1P_1^0$. The polarizabilities of both mentioned above states are positive. Moreover, the polarizability of 6s5d $^3D_2$ is 50 times as much as polarizability of 6s5d $^3D_1$. I.e. under the increase of laser field strength 6s5d $^3D_2$ state must shift more rapidly than 6s5d $^3D_2$. At some values of field strength of CCL the variation of energy of 6s5d$^3D_2$ state will equal to the difference between energies of 5s5d $^3D_2$ and 5s5d $^3D_1$ states. In result the mixing of these states could set in.

For testing of the energies of these levels we used the excitation and subsequent ionization of them. We used the radiation of dye laser (DL) with frequency ω_2=17735 cm^{-1} for excitation. During simultaneous action of this radiation and CCL radiation the Raman processes of excitation of perturbed 5s5d $^3D_2$ and 5s5d $^3D_1$ states could be realized. Ionization of these states was realized by radiation of both CCL and DL. We have measured the yield of Ba^+ ions as function of frequency of CCL radiation. The field strength of CCl radiation was ε ~10^6 V/cm. The typical results of these investigations obtained at $\varepsilon=5\times10^6$ V/cm are shown in Fig. In this case in $N^+(\omega_1)$ yield one can see three maxima. The analisis show that maximum "A" is caused by excitation of unperturbed 6s5d $^3D_1$ state. Other two maxima ("B" and "C") are caused by excitation of mixed in result of strong perturbation of 6s5d$^3D_2$ and 6s5d$^3D_1$ states.



COMPTON EFFECT IN THE PRESENCE OF TWO STRONG LIGHT WAVES

O.I. Denisenko

Assistant Professor of General Physics Department of Sumy State University

S.P Roshchupkin

Full professor of General Physics Department of Sumy State University

Sumy State University, 2 Rymsky-Korsakov St., Sumy, 40007 Ukraine

tel/fax: 38 (0542) 33 40 58, e-mail: deo@ssu.sumy.ua rosksp@ssu.sumy.ua

Non-resonant scattering of a photon by an electron in the field of two elliptically polarized waves that propagate in the same direction is studied theoretically in the general relativistic case. As it is shown there are two substantively different cinematic areas. The first one is a non-interference region where the multiphoton parameter is an intensity of the waves. Another one is an interference region where correlated emission and absorption of equal number of the photons of both waves is manifested itself and where the interference parameters act as multiphoton parameters. The interference effect occurs in the two situations, when the both waves are linearly polarized in the same plane and in the general case of elliptical polarization of the both waves. The cross sections of Compton scattering is obtained for moderately strong fields in the given areas. As it is shown the cross section of the interference region may considerably exceed the scattering cross section in any other geometry.

Acknowledgments. We are grateful to the Deutsche Forschungsgemeinschaft (grant no. 436 RUS 113/536/O) and to the Russian Foundation for Basic Research (grants no. 99-02-04021 and 00-02-17078) for partial financial support.

References

[1] C.G. Durfee I 11, A.R. Rundquist, S. Backus, C. Herne, Ivl.M. Miurnane, HO. Kapteyn. Phys. Rev. Lett. 83 (1999) 2187. E. Constant, D. Garzella, P. Breger, E. Mével, Ch. Dorrer, C. Le Blanc, F. Salin, P. Agostini, Phys. Rev. Lett. 82 (1999) 1668.

[2] D.F. Zaretskii. E.A. Nersesov, Zh. Exp. Teor. Fiz. 109 (1996) 1994. D.F. Zaretskii, E.A. Nersesov, Zh. Exp. Teor. Fiz. 112 (1997) 1978.

Scattering of Relativistic Electrons in a Head-on Collision with a Focused Laser Pulse

M.S. Fofanov

Moscow Engineering Physics Institute, Moscow, 115409, Russia e-mail: fofanov©pclk32.mephi.ru

Scattering of classical relativistic electrons by a spatially and temporally inhomogeneous laser pulse is considered. An electron beam and a laser pulse are assumed to propagate toward one another before the collision. The three-dimensional field model proposed recently (1) is used for description of the field of a laser pulse. In a weakly inhomogeneous laser pulse the equations of motion for an electron are solved by a standard technique involving separation of electron motion into a systematic motion along a continuous trajectory (averaged motion) and rapid oscillations around this trajectory. The obtained equations of averaged motion can imply axial-asymmetric ponderomotive potential which leads to asymmetry in axial distribution of scattered electrons.

The scattering angle decreases with increasing electron energy. For ultra-relativistic electrons (with energies much more than the maximum value of ponderomotive potential) one can neglect the transversal displacement of an electron during its interaction with a laser pulse. This result approves the method for calculation of probability of photon emission by an electron colliding with a short focused laser pulse developed in (2).

This work is supported in part by the Russian Foundation for Basic Research (grant no. 00-02-17078)

1) NB. Narozhny and MS. Fofanov, Zh. Exp. Teor. Fiz.117, (2000).

2) NB. Narozhny and M.S. Fofanov, Zh. Exp. Teor. Fiz.11O, 26 (1996).

Non-sequential double ionization of small molecules induced by a femtosecond laser field

Ph. Hering and C. Cornaggia

CEA Saclay, Division des Sciences de la Matière

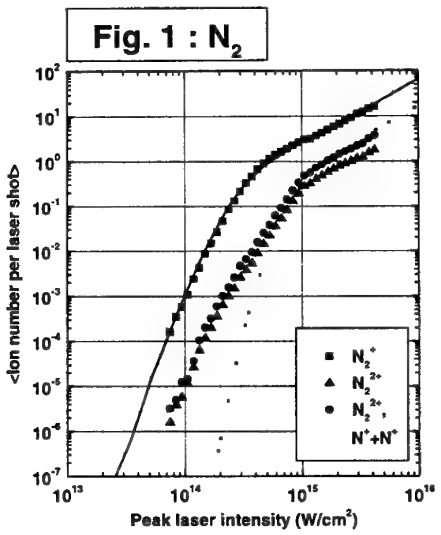
Service des Photons, Atomes, et Molécules, Bât. 522

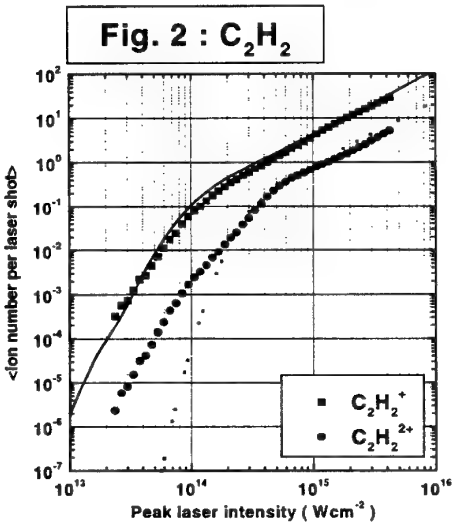
F-91 191 GIF-SUR-YVETTE, FRANCE

Tél : (33) 1 69 08 96 65 Fax : (33) 1 69 08 90 63

E-mail : cornaggia@drecam.cea.fr

Non-sequential double ionization of several neutral molecules is identified from the ion yield measurements in comparison with a sequential ionization model in the 10^{13}-10^{15}





W/cm^2 laser intensity range at λ = 800 nm (Fig.1 for N_2, and Fig.2 for C_2H_2 using linearly polarized laser light. The sequential model predictions are represented using continuous and dotted curves for respectively the singly charged molecules and the total contribution of the two-missing electron decay channels).

This effect is observed mainly using linear polarization. In circular polarization, non-sequential double ionization might be present for instance for C_2H_2, but with a much lower contribution than in linear polarization. The experimental method allows to detect all the double ionization decay channels, that are mainly the molecular dication and the two-missing electron fragmentation channels. Results will be presented for several molecular species in order to discuss the validity of several existing models of non-sequential double ionization.

Multiphoton resonance processes in dipole molecules In the presence of polar medium fluctuations

V.A.Kovarsky, O.B.Prepelitsa

2028, Institute of Applied Physics, Academy of Sciences of Moldova, ω

Academiei str. 5, Kishinev, Moldova, E-mail: referнt@prozelit.com

It is investigated the multiphoton resonance in impurity dipole molecule, which interacted with the surrounding dipole medium. Such influence of polar medium on the nonradiative transitions in polar molecules was analyzed before (see for example [1-3]). The fluctuations of the polar medium are described by the Gauss-Marcov process with the damping constant γ. Our analyses show that fluctuations of the polar environment lead to the change in the multiphoton resonance transition probability. The ratio between the damping constant γ and the frequency of molecular vibrations ω determines this change. The theory predicts anomaly temperature dependence of the transition probability W on the temperature T. So $W \sim \exp(T/A)$, where A is a constant, for slow fluctuations $\gamma/\omega << 1$ and $W \sim 1/T$ for fast fluctuations $\gamma/\omega >> 1$.

1.I.Sh.Averbukh, V.A.Kovarsky, A.A.Mosiak, N.F.Perelman, Teoreticheskaia i matematicheskaia fizika, **81**, 271, 1989 [Sov. TMP **81**, 271, 1989].

2. I.Sh.Averbukh, V.A.Kovarsky, A.A.Mosiak, N.F.Perelman, Kinetics effects in molecules in external fields (in Russian), Shtiintsa, Kishinev, (1990).

3. A.V.Belousov, V.A.Kovarsky, Zh. Eksp. Teor. Fiz. **81**, 271, 1989 [Sov. JETP, **114**, 89, 1998].

Quasistationary Quasienergy State Theory of Harmonic Generation

N. L. Manakov*, B. Borca†, A. V. Flegel*, M. V. Frolov* and A. F. Starace†

*Voronezh State University, Voronezh, 394693, Russia; E-mail: manakov@thp.vsu.ru

†The University of Nebraska, Lincoln, NE 68588-011, USA

Only a few analytic models exist for high harmonic generation (HHG) by atoms in a strong laser field, $\mathbf{F}(\mathbf{r},t) = F\mathrm{Re}\{\mathbf{e}\,\exp[i(\mathbf{k}\cdot\mathbf{r}-\omega t)]\}$. Even the simplest of them, the well-known three-step model, gives a clear explanation of the global characteristics of HHG spectra for the case of linear polarization of $\mathbf{F}(\mathbf{r},t)$. Nevertheless, for more subtle properties, such as the polarization parameters of harmonics produced either by an elliptically-polarized laser or in the presence of a strong static electric field, $\vec{\mathcal{F}} = \mathcal{F}\mathbf{e}_0$, the accuracy of different models is unclear. Moreover, the so-called "dipole expectation value" and "S-matrix" methods lead to formally different results for the generation amplitude. For the lowest harmonics, especially for laser frequencies ω comparable with the ionization potential of an atom, the validity of some commonly used approximations (e. g., the saddle-point method) is not evident. Finally, for strong fields, the influence of level shifts and widths of atomic levels on the harmonic parameters should be properly estimated. Treatment of HHG in instances such as these clearly requires a more thorough analysis.

We present here an *ab initio*, nonperturbative theory of HHG employing quasistationary, quasienergy states (QQES) or non-Hermitian Floquet states, $\Phi_{\mathcal{E}}(\mathbf{r},t)$, where $\mathcal{E}$ is the complex quasienergy, for an atom in a strong laser field (and possibly also a static electric field). Because of their asymptotically divergent terms in r (in the open ionization channels), the QQES wavefunctions are not normalizable in the standard way; thus matrix elements of the dipole emission operator $\mathbf{r}$ between QQES functions diverge when calculated in the usual way. Instead, properly normalized (dual) functions, $\tilde{\Phi}_{\mathcal{E}}(\mathbf{r},t)$, must be used as bra-vectors in a calculation of transition matrix elements, as when using quasistationary states in radiationless problems. In the presence of two fields, $\vec{\mathcal{F}}$ and $\mathbf{F}(\mathbf{r},t)$ with an arbitrary elliptical polarization, the proper dual functions are given by

$$\tilde{\Phi}_{\mathcal{E}}(\mathbf{r},t) = [\Phi_{\mathcal{E}}(\mathbf{r},-t;\xi\to-\xi)]^*, \tag{1}$$

where $\xi = i\hat{\mathbf{k}}\cdot[\mathbf{e}\times\mathbf{e}^*]$ is the circular polarization degree of $\mathbf{F}(\mathbf{r},t)$ and $\mathbf{k} = \hat{\mathbf{k}}(\omega/c)$. The time-dependent (complex) dual dipole moment is thus calculated as

$$\tilde{\mathbf{d}}(t) = \langle\tilde{\Phi}_{\mathcal{E}}(\mathbf{r},t)|\mathbf{r}|\Phi_{\mathcal{E}}(\mathbf{r},t)\rangle = \frac{1}{2}\sum_n \tilde{\mathbf{d}}_n e^{-in\omega t}. \tag{2}$$

The nth Fourier-coefficient, $\tilde{\mathbf{d}}_n$, of Eq. (2) has the following representation in terms of the vectors involved, $\tilde{\mathbf{d}}_n = \chi_1\mathbf{e} + \chi_2\mathbf{e}^* + \chi_3\mathbf{e}_0$, where the complex scalars, $\chi_{1,2,3}$, are the nonlinear susceptibilities and $\chi_3 = 0$ for $\mathcal{F} = 0$. This expression for $\tilde{\mathbf{d}}_n$ is used for the generation amplitude of the nth harmonic, $A_{n\omega}(\mathbf{e}') = \mathbf{e}'^*\cdot\tilde{\mathbf{d}}_n$, with unit (complex) polarization vector $\mathbf{e}'$.

We computed the susceptibilities $\chi_{1,2,3}$ using a 3-dimensional zero-range potential for the atom. If the quasienergy $\mathcal{E}$ is approximated by the unperturbed binding energy, E_0, of the model atom, and if all but the leading Fourier-coefficients of $\Phi_{E_0}(\mathbf{r},t)$ at the origin ($r\to 0$) are neglected, then our approximate QQES result for the amplitude $A_{n\omega}(\mathbf{e}')$ coincides with the result of the S-matrix approach, provided that the latter takes into account the so-called "continuum-continuum coupling". Examples of numerical calculations will be presented both for HHG by an elliptically-polarized laser and in the presence of a static electric field.

This research is supported in part by the following Grants: INTAS-RFBR (No. 97-673)), RFBR (No. 00-02-17843), and NSF (No. PHY-9722110).

Ionization Effects in High-Order Harmonic Generation in Gas-Filled Hollow Fibers

A. N. Naumov*, A. M. Zheltikov*, A. B. Fedotov*, D. A. Sidorov-Biryukov*, A. P. Tarasevitch, Ping Zhou**, and D. von der Linde****

*** International Laser Center, Faculty of Physics, Moscow State University, Moscow, Russia**
**** Institut für Laser- und Plasmaphysik, Universität Essen, Essen, Germany**

Rapidly growing applications of hollow fibers for the generation of ultrashort pulses [1] and frequency conversion [2] have raised a number of issues associated with the choice of optimal parameters of hollow fibers, as well as the gas sort and gas pressure. Understanding of the role of these factors in harmonic generation and wave mixing in gas-filled hollow fibers will provide many degrees of freedom in controlling nonlinear-optical interactions and generating ultrashort pulses of short-wavelength radiation. With this motivation in mind, we theoretically studied the influence of ionization in high-order harmonic generation in hollow fibers.

To include ionization effects, we assume that a small part of particles of the gas filling the fiber may be ionized during the pump pulse, giving rise to an electron addition to the refractive index of the gas and, consequently, to the phase modulation of the pump pulse. Due to the change in the phase of the pump pulse from its leading edge to the trailing edge, the phase mismatch for harmonic generation changes within the pump pulse, and the phase mismatch in an ionizing gas is a function of time. Therefore, different pressures would be required to phase match harmonic generation at different the leading and trailing edges of the pump pulse (Fig. 1). The net effect of ionization occurring in the gas filling the fiber is that it decreases the overall efficiency of harmonic generation and makes the harmonic-generation efficiency less sensitive to the gas pressure in the hollow fiber.

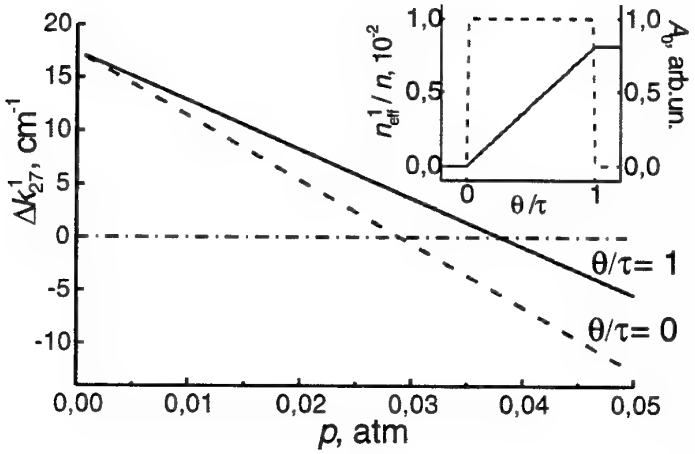


Fig. 1. The phase mismatch for the 27th harmonic of 790-nm fundamental radiation generated in a hollow fiber with an inner diameter of 75 μm filled with argon as a function of the gas pressure p (dashed line) on the leading edge of the pulse, where ionization does not play an important role, and (solid line) on the trailing edge of the pulse, where 0.8% of atoms is ionized. The transverse distribution of the pump intensity corresponds to the EH_{11} waveguide mode. The pump pulse has a rectangular shape (the dashed line in the inset), giving rise to a linear growth in the effective electron concentration as a function of time θ (the solid line in the inset); n is the concentration of argon atoms, τ is the pulse duration.

This study was supported in part by the President of Russian Federation Grant no. 00-15-99304, INTAS project no. 97-0369, and the Russian Foundation for Basic Research project no. 00-02-17567.

1. M. Nisoli, S. De Silvestri, and O. Svelto, *Appl. Phys. Lett.* **68**, 2793 (1996); M. Nisoli, S. De Silvestri, O. Svelto *et al.*, *Opt. Lett.* **22**, 522 (1997).
2. C.G. Durfee III, S. Backus, M.M. Murnane, and H.C. Kapteyn, *Opt. Lett.* **22**, 1565 (1997); Z. Chang, A. Rundquist, H. Wang *et al.*, *Phys. Rev. Lett.* **79**, 2967 (1997); A. Rundquist, C.G. Durfee III, Z. Chang, C. Herne, S. Backus, M.M. Murnane, H.C. Kapteyn, *Science*, **5368**, 1412 (1998); E. Constant, D. Garzella, P. Breger, E. Mevel, *et al. Phys. Rev. Lett.*, **82**, 1668 (1999).

QUANTUM EFECTS WITHOUT QUANTUM FIELDS IN COMPTON-LIKE PROCESS

Huber Nieto
Seccion de Fisica
Pontificia Universidad Catolica del Peru

We studied the effects of classical fields in Compton-like scattering, from a point of view of Green's functions, as simple as multiple scattering for a collision between a free electron and intense laser. Amplituds are calculates whit this method and histograms of multiple photonic absortion are showed for differents values of intensity parameter. Nonlineal effects are present when the laser is superintense and limits in the lineal region are given.

Dynamics of single and double ionisation of N_2 with intense laser pulses.

Alexander I. Pegarkov

Faculty of Physics – Voronezh State University
1 Universitetskaya Ploschad
Voronezh 394693 – Russia
e–mail : alexander.pegarkov@niif.vsu.ru

Eric Charron and Annick Suzor–Weiner

Laboratoire de Photophysique Moléculaire
Université Paris XI – Bâtiment 213
91405 Orsay cedex – France
e–mail: eric.charron@ppm.u–psud.fr
e–mail: annick.suzor–weiner@ppm.u–psud.fr

We present a theoretical treatment for the single and double ionisation of molecules in strong laser pulses, including the effect of electron correlations. Applied to a model N_2 molecule, our simulations show that double ionisation occurs via a direct two–electron mechanism at moderate laser intensities :

$$N_2 \rightarrow N_2^{2+} + 2\,e^-,$$

while a step–by–step sequential ionisation process dominates at higher intensity :

$$N_2 \rightarrow N_2^{+} + e^- \rightarrow N_2^{2+} + 2\,e^-.$$

At intermediate intensity, these two mechanisms have a comparable contribution to the total double ionisation yield. This phenomenon is directly reflected on the spatial distributions of N_2^{+} and N_2^{2+} in the focal volume of the laser pulse. In addition we show that at high intensity the singly and doubly charged molecular ions are created in well separated regions of space.

References :

C. Cornaggia and Ph. Hering *J. Phys. B* **31**, L503 (1999).

A. I. Pegarkov, E. Charron and A. Suzor–Weiner *J. Phys. B* **32**, L363 (1999).

Test of Bi-Maxwellianity on Numerical Distribution Functions of Laser-Embedded Plasma

O.Petrova[*] and G.Ferrante

Istituto Nazionale di Fisica della Materia and Dipartimento di Fisica e Tecnologie Relative, Viale delle Scienze, 90128 Palermo, Italy

For correct and efficient applications of laser-plasma interactions is an important prerequisite a good knowledge of the velocity distribution function of plasma electrons interacting with the laser radiation. The first interesting results in this context were obtained in early eigthies, where it was shown that, when electron-electron collisions may be neglected and the laser field is not very strong, in the late stages of interaction the electrons have a velocity distribution function significantly different from the maxwellian. These results had a significant impact on applications (plasma heating, transport properties, etc) and later on were extended to include the effect of electron-electron collisions as well. Perhaps the most pecular result was that the laser-modified distribution function , as compared to the maxwellian , exhibited a considerably smaller number of slow electrons, and it impacted negatively on heating and plasma laser recombination schemes, and other applications as well.

In more recent years, several authors have addressed the issue of anisotropic plasma electron distribution functions, and an important stimulus has been provided by experiments on laser tunnel ionization showing that ionization produced a highly anisotropic two-temperature plasma. In some cases, the real distribution function of plasma electrons acted by a strong laser field may approach a bi-maxwellian distribution. As for applications is particulary important to have a good analytical approximation to the real distribution, we have performed tests of bi-maxwellianity under various conditions on our distribution, obtained numerically solving the corresponding kinetic equation. We anticipate that the calculated distribution is well approximated by a bi-maxwellian. However, significant departures are always observed in two conditions: a) in the initial stages of laser-plasma interactions, and b) in the portion of velocity space concerned with slow electrons.

---

[*] On leave of absence from: Chemical Physics Laboratory, Heat and Mass Transfer Institute, P.Brovki str. 15, 220072 Minsk, Belarus

Off-axial phase-matched high-order harmonic generation in extended medium under self-channeling of laser beam.

V. T. Platonenko, V.V.Strelkov,

Physics Department, M.V.Lomonosov Moscow Sate University

Vorob'evy gory, 119899 Moscow, Russia. e-mail: strelkov@orc.ru

G. Ferrante

Department of Physics and Related Technologies, University of Palermo

Vialle delle Scienze, 90128, Palermo, Italy

We present analytical and numerical calculations of the power and angular spectrum of the power of high-order harmonics generated with a limited laser beam in an extended medium. It is shown that the spectrum of harmonics generated in a thick target dramatically differs from the spectrum of the single-atom response. In particular, there are *two* plateaus in this spectrum due to the off-axially phase-matched generation of some harmonics (the generation of a part of the angular spectrum of these harmonics is phase-matched [1]). The origin that makes the off-axially phase-matched generation effective is the amplitude modulation of the high-frequency single-atom response in laser beam cross-section that increases divergence of a harmonic beam.

Off-axially phase-matched harmonic generation in Gaussian beams is effective with any geometric dispersion (i.e. with an arbitrary tight focusing). Harmonic spectrum generated with a Gaussian beam is qualitatively close to one generated with a beam propagating in a wave-guide. The harmonic yield growth approximately linearly with the wave-guide length. Presented results agree well with the experimental data on high-order harmonic generation in thick neon targets available from the literature.

We discuss the off-axial phase-matched high-order harmonic generation with a self-guided laser pulse in noble gases. The self-guided propagation results from a dynamic quasiequilibrium between beam convergence due to self-focusing and beam divergence due to diffraction and influence of free electrons (that appear in the medium due to multiphoton ionization). The self-guided pulses have the intensity fixed by onset of ionization and therefore suitable for high-order harmonic generation. Unfortunately, calculations show that high harmonic generation with a self-guided laser pulse propagating in any noble gas is phase-matched only in rather thin target. The phase-matching can be improved by presence in the medium a certain additional number density of free-electrons. To provide it we propose adding an easy-ionizing buffer gas to the main generating gas: during propagation of the pulse through the mixture the addition to the free electrons number density appears due to ionization of the buffer. Calculations show that the off-axial phase-matched high harmonic generation with self-guided laser pulses in the gas mixtures takes place in targets about 1 cm thick. The conversion efficiency of such generation is limited mainly with harmonic absorption. Under some assumptions concerning the absorption we obtain in calculations conversion efficiencies 0.1%-1% for generation of 29-th harmonic in mixture of xenon and cesium and 0.001%-0.01% for generation of 117-th harmonic in mixture of neon and xenon.

1. V.T.Platonenko, V.V.Strelkov, Quantum Electronics, Vol. **30**, No 3 (2000).

High harmonic generation in an atomic jet and a hollow-core fiber.

S.V.Popruzhenko
Moscow Engineering Physics Institute, Moscow, 115409, Russia
E-mail: poprz@theor.mephi.ru\\}

April 17, 2000

In the recent experiments [1] the high-order harmonic generation (HHG) in the atomic jet and the hollow-core fiber has been investigated. The main result obtained in [1] is that the efficiency of HHG in the fiber is substantially larger than in the jet.

We present a simple analytical calculation of HHG in an atomic jet and a fiber. The number of $s-th$ harmonic quanta per laser pulse N_s was calculated with consideration for the phase-matching conditions [2] as a function of the atomic concentration n_0 in the jet or fiber. In the case of the atomic jet the result is:

$$N_s \sim d^2 n_0^2 exp\{-u^2\}$$

where $u = \frac{\pi s d}{2\lambda}\frac{\omega_p^2}{\omega^2} \sim dn_0$; ω_p - plasma frequency of and d is the jet diameter.

Therefore, at fixed parameters of the pumping wave the harmonics yield is a function of one variable $x = dn_0$, which provide a scaling law in the density dependence of harmonic yield. As a result, the maximum number of harmonic quanta is independent from the jet diameter. The position of this maximum depends on the d as $n_0^{max} \sim 1/d$.

In the fiber the pumping wave gets the transverse component of the wave vector $k_\perp = \theta_f k_z$. The existence of the angle θ_f leads to an effective decrease of the refractive index $n(\omega)$:

$$n(\omega) \to n_{\text{eff}}(\omega, \theta_f) = 1 - \frac{\omega_p^2}{2\omega^2} - \frac{\theta_f^2}{2}$$

As a result, the scaling law in the density dependence of harmonic yield breaks down and the maximum number of HH becomes an increasing function of the interaction length.

The density dependence of the $15th$ harmonic of a Ti:sapphire laser is evaluated from (1) and (2). The parameters of the atomic target and the laser field correspond to the conditions of the experiments [1]. The results of calculations are in good agreement with the experimental data [1].

Distribution in the net electron momentum for double ionization.

S.V. Popruzhenko

Moscow State Engineering Physics Institute, 31 Kashirskoe shosse, Moscow, 115409, Russia
e-mail:poprz@theor.mephi.ru

The recoil momentum distribution of multiply charged ions created by intense short laser pulses has been measured in a recent experiment [1]. In this talk the distribution in the net electron momentum is calculated for double ionization of atoms and compared with the experimental data.

Double ionization is studied in frame of the generalized Keldysh approach [2,3] assuming the tunneling regime, $\gamma = \omega\sqrt{2I}/F << 1$. Quantum amplitude of the process is calculated by a saddle – point method in the manner used for elastic rescattering in [4,5]. In this way the resulting distribution in the net and relative momenta of the two emitted electrons is formulated in terms of the semiclassical three – step model. It contains, among other factors, the Born cross section for impact $(e,2e)$- ionization produced by the returning electron.

Further on integration over the relative momentum is carried out to derive the distribution in the net electron momentum. The result is shown in Fig. 1.

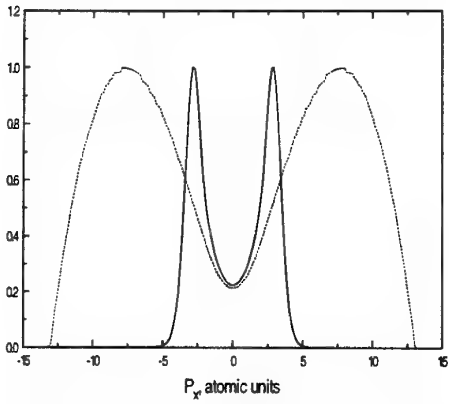


Fig. 1: The distribution in projections of the net electron momentum onto the direction of laser polarization. Solid curve is calculated from the derived formula with the parameters used in [1] (radiation $795nm$, at $1.5 10^{15} W/sm^2$ and Ne^{2+}). Dashed curve is obtained in the same calculations but with a „flat" cross section $\sigma(e \to 2e)$ independent on the returning electron energy.

Both shape of the calculated distribution and positions of the maxima at $\pm 3{,}1 a.u$ are in a fair agreement with the measured recoil momentum distribution for Ne^{2+} ions [1] where the maxima are found $\pm 4 a.u$. The impact from the exchange effects does not exceed 20%.

This work was partially supported by the Russian Foundation for Basic Research (projects 99-02-17810 and 00-02-17078)

References.

1. Moshammer R et al, Phys. Rev. Lett (in press)
2. Kuchiev M, J. Phys. B: At. Mol. Opt. Phys. 28, 5093 (1995)
3. Faisal F H M, Becker A, NATO ASI Series, Ser. 3:, 13, 317 (1996)
4. Goreslavskii S P, Popruzhenko S V, Phys. Lett. A .249, .477.(1998)
5. Goreslavskii S P, Popruzhenko S V, J. Phys. B: At. Mol. Opt. Phys. 32, L533. (1999)

Disappearance of the dressed bound states in photodetachment from a short range potential by an intense high-frequency laser field

R. M. Potvliege[1]

Physics Department, University of Durham, South Road, Durham DH1 3LE, UK

It is proved that in three dimensions, and contrary to what is usually found in one dimension, the number of bound KH states always reduces to zero in strong fields if the range of the potential is short and its depth finite. Numerical results showing the disappearance of the dressed ground state of an exponential potential in an intense high frequency field are also presented.

[1]e-mail: R.M.Potvliege@durham.ac.uk

Excited multi-charged atomic fragments coming from laser-induced Coulomb explosion of molecules

L. Quaglia and C. Cornaggia

CEA Saclay, Division des Sciences de la Matière

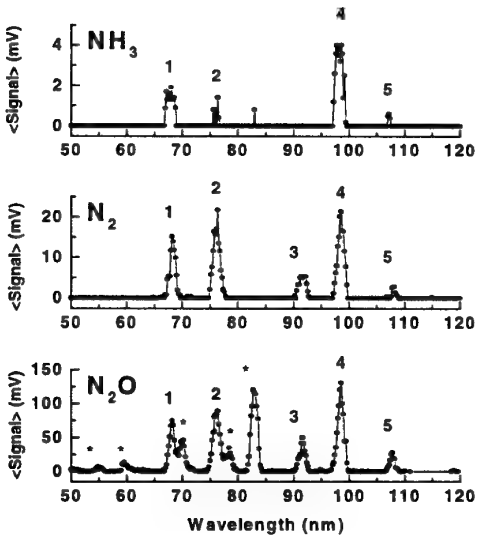
Service des Photons, Atomes, et Molécules, Bât. 522

F-91 191 GIF-SUR-YVETTE, FRANCE

Tél : (33) 1 69 08 96 65 Fax : (33) 1 69 08 90 63

E-mail : cornaggia@drecam.cea.fr

Laser-induced Coulomb explosion of molecules is currently studied using time-of-flight mass spectrometry, in order to determine the fragmentation channels and the associated kinetic energy releases. Major advances have appeared during the last past years in the theoretical understanding of the laser-molecule coupling. However, the degrees of excitation of the detected multi-charged fragments remain largely unknown. This work reports a first experimental evidence for excited multi-charged fragments for diatomic and polyatomic molecules. Systematic studies as a function of the initial gas pressure show that the photon emission is a unimolecular process and comparisons with different atomic and molecular precursors show that the excited fragments come from transient excited multi-charged molecules.



The atomic fluorescence spectra recorded for NH_3, N_2 and N_2O in the 50-150 nm wavelength range (Figure) shows that the excitation increases noticeably from NH_3 to N_2O. This effect is interpreted in terms of the initial electronic structure, which favors stronger excitation when the electronic density is delocalized. The N^{Z+} lines intensities (No1-5 in Figure) are in qualitative agreement with these ions yields in the time-of-flight spectra recorded using the same laser excitation conditions.

Connection between the strong field approximation (SFA) and the high frequency approximation (HFA)

H.R. Reiss
Physics Department, American University, Washington, DC 20016-8058, USA

By a simple formal transformation in the transition matrix element for atomic photoionization, it is shown that the Volkov solution employed in thetime-reversed matrix element of the SFA becomes exactly the outcome of a Kramers-Henneberger transformation in the direct-time matrix element employed in the HFA. This result demonstrates several things. First, it is now clear how the «F» and «R» parts of the so-called KFR (Keldysh-Faisal-Reiss) approximation are related. The F and R results are analytically identical for nonrelativistic calculations, as has long been known, but whereas R comes from a strong-field approximation, F is shown to be the result of a high-frequency approximation. This explains the close numerical correspondence that has been found between calculated ionization rates in the context of SFA and of HFA calculations as done by Gavrila. That is, the SFA is now formally shown to be valid at high frequencies. The difference in the physical interpretation of the calculation of high-frequency ionization as done by the SFA and by Gavrila's HFA is easily understood. Apart from small differences in dynamical results that arise from procedural matters, the two methods yield the same answers, since they differ only by a gauge transformation that removes the ponderomotive energy in Gavrila's calculations. As the amount of the ponderomotive energy surpasses the energy of individual high-frequency photons, the SFA shows apparent channel closings since more photons are needed to overcome the ponderomotive energy. The Gavrila calculations are not done in the laboratory frame of reference because of the gauge transformation, and the need to overcome the ponderomotive energy (and hence to have channel closings) seemingly doesn't arise. A simple energy diagram illustrates this elementary connection between SFA and HFA energetics.

INTERFERENCE EFFECTS IN THE STRONG FIELD OF TWO LIGHT WAVES

S.P. Roshchupkin

Professor of General Physics Department of the Sumy State University

Sumy State University, 2. Rymsky-Korsakov – St., Sumy, 40007 Ukraine

tel./fax: 38 (0542) 33-40-58; e-mail: rosh_sp@ssu.sumy.ua

This report presents, for the general relativistic case, the generalization of interference effects, predicted earlier for some elementary quantum processes [1-5], on a series of processes of a quantum electrodynamics in the strong field of two light waves propagating in the same direction (emission of a photon by an electron, production of an electron - positron pair by a photon, scattering of an electron by a nucleus, spontaneous bremsstrahlung in the scattering of an electron by a nucleus, photoproduction of an electron - positron pairs by a nucleus). For the given of processes of a quantum electrodynamics is shown that there are two significantly different kinematic region: the noninterference region where the main multiphoton parameters are Bunkin-Fedorov quantum parameters (or classical parameters for each of waves), and the interference region where interference effects play an important role and where the interference parameters act as multiphoton parameters. The interference effect manifests itself in the interference region and is due to stimulated, correlated emission and absorption of photons of both waves. It is important to note, that the power and kinematic relations in the interference regions essentially differ from the corresponding relations in the noninterference regions. For moderately strong fields, the cross sections of these processes in the given kinematic regions are obtained. Is finally shown, that the differential cross section of investigated processes of a quantum electrodynamics in the interference regions with correlated emission (absorption) of equal numbers of photons of both waves can be much greater than the corresponding cross section in any other geometry.

1. Roshchupkin, S.P., 1994, Zh. Eksp. Teor. Fiz., **106**, 102 [1994, JETP, **79**, 54].
2. Roshchupkin, S.P., 1996, Zh. Eksp. Teor. Fiz., **109**, 337 [1996, JETP, **82**, 177].
3. Voroshilo, A.I. and Roshchupkin, S.P., 1997, Laser Phys., **7**, 466.
4. Roshchupkin, S.P. and Lusenko, O.B., 1999, Laser Phys., **9**, 494.
5. Roshchupkin, S.P. and Lusenko, O.B., 1999, Zh. Eksp. Teor. Fiz., **116**, 1210 [1999, JETP, **89**, 647].

SPECTRUM OF BREMSSTRAHLUNG BY AN ELECTRON SCATTERED BY A NUCLEUS IN THE FIELD OF TWO STRONG LIGHT WAVES

S.P. Roshchupkin

Full professor of General Physics Department of the Sumy State University

O.B. Lusenko

Post-graduate of General Physics Department of the Sumy State University

Sumy State University, 2. Rymsky-Korsakov – St., Sumy, 40007 Ukraine

tel./fax: 38 (0542) 33-40-58; e-mail: rosh_sp@ssu.sumy.ua

This report presents a theoretical study of the bremsstrahlung spectrum by an electron scattered by a nucleus in the field of two elliptically polarized light waves propagating in the same direction. Shown, that there are two significantly different kinematic regions (noninterference region and interference region), in which the bremsstrahlung spectrum has essentially different nature. In noninterference region, for moderately strong fields, the bremsstrahlung spectrum has typical appearance (as without external field). In interference region we have found that the frequency of the spontaneous photon has an upper bound, which depends on the energy and polar incidence angle of initial electron. The exit angles of the electron and spontaneous photon are highly correlated and depend heavily on the energy of the initial electron. Finally, we have shown that the differential cross sections with correlated emission (absorption) of equal numbers of photons of both waves, with emission of a spontaneous photon of given energy and in a given direction, and with the scattering of the electron to a given angle (correlated with the angle of the spontaneous photon) , can be much greater than the corresponding cross section in any other geometry.

RELATIVISTIC MODIFICATION OF HIGH-ORDER HARMONIC SPECTRA GENERATED BY MULTICHARGED IONS: EFFECTS OF PLATEAU DROP AND CUT-OFF SUPPRESSION

Shubin N.Yu., Taranukhin V.D.

Physics Dept., Moscow State University, Vorobievy gory, Moscow 119899, Russia

Tel: (095)9390155, fax: (095)9393113, e-mail: shubin@magn.phys.msu.su

We investigate high-order harmonic generation (HHG) by multicharged ions in a laser field of relativistic intensity within a frame of a semiclassical model. An essential suppression of harmonic intensity due to relativistic displacement of the photoelectrons along the pump field wavevector is shown by model simulations and explained in terms of a relativistic "simpleman" analysis.

The ultimate HHG frequency Ω is limited by the saturation of ionization for neutral atoms. It is possible to overcome this limitation using multicharged ions. Further we consider Ar^{8+} and pump field frequency $\omega \approx 3$ eV. In this case considerable restrictions on HHG arise due to relativistic effects [1]. Longitudinal displacement of photoelectron released to the continuum at time t_0 leads to electron missing the parent ion (when it returns to ion at time t_r with kinetic energy E (Fig. 1)) and so prevents electron recombination and HHG. This limits the increase of HHG cut-off frequency Ω.

Assuming a gaussian profile of the photoelectron wavepacket in the transversal direction, the following estimate can be made for the relative decrease of a harmonic intensity: $\eta \sim \exp(-(z/\sigma)^2)$ where $\sigma \approx V_{sp} \cdot \tau$ is wavepacket width, $\tau = (t_r - t_0)$. We consider both the intensity and phase dependencies of longitudinal displacement $z \approx V_{dr}(I, t_0) \cdot \tau$ and of the photoelectron wavepacket spreading velocity V_{sp} (Fig. 1). Since $z \sim I$ and $V_{sp} \sim I^{1/4}$, relative suppression of harmonic intensities occurs with the pump intensity increase, so the cut-off harmonic intensity relative decrease is $\eta_\Omega \sim \exp(-(I/I_t)^{3/2})$. ($I_t \sim \omega^{8/3}$ is the intensity of the onset of relativistic regime of HHG [1]). This estimate agrees well with the relativistic model calculation of HHG spectra (Fig. 2) and yields relative decrease of the cut-off harmonic intensity of 10^{-6} (in comparison with the non-relativistic case) for $I \sim 10^{19}$ W/cm^2.

Due to non-monotonous behavior of $E(t_0)$ (Fig. 1), two classical trajectories usually contribute to each harmonic in the plateau region. However, for Ar^{8+} and $I \sim 10^{19}$ W/cm^2 only the one with t_0 closer to the field maximum contributes essentially to the spectrum, due to its essentially greater ionization probability. The greater velocities V_{dr} for smaller t_0 (see Fig. 1) cause stronger suppression of the low-frequency (LF) part of the HHG spectrum ("burning" of the plateau LF part). The estimate for the relative decrease of a plateau intensity takes the form $\eta \sim \eta_\Omega^\alpha$, where $\alpha = (V_{dr}(t_0)/V_{dr}(t_\Omega))^2$, $\omega t_\Omega = 0.3$ is the ionization phase that yields cut-off frequency ($\alpha \approx 1.8$ corresponds to the central part of the plateau). Fig.2 shows the HHG spectrum ($I = 4 \cdot 10$ W/cm^2) suppressed due to relativistic effects (solid line) and a spectrum obtained in model calculation without taking the relativistic effects into account (dashed line).

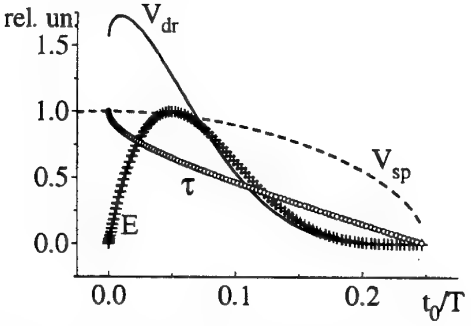


Fig. 1

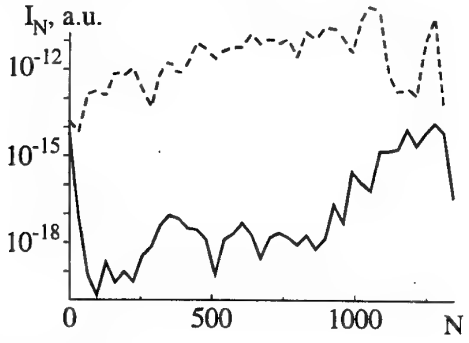


Fig. 2

This work was supported by RFBR (grant No. 00-02-17533).

1. Taranukhin V.D. *Laser Physics*, **10**, 330 (2000).

On the applicability of the Kramers-Henneberger approximation.

O.V. Smirnova

Moscow State University, Moscow, 119899, Russia

The formal analogy between the classical method of averaging and the Kramers-Henneberger method [1] of approximate description of the dynamics of atomic systems in a strong monochromatic field is employed to determine the applicability boundaries of the Kramers-Henneberger approximation. Using a unified approach, based on the Bogolyubov theorem, we obtain the well-known result that the Kramers-Henneberger approximation is applicable ïn the limiting case of superatomic frequencies and demonstrate that this approximation is also valid when the above specified condition is violated and the field frequency is decreased down to some value ω_{cut}. In this case the Kramers-Henneberger approximation is valid in the limit of superatomic field when an additional requirement on the Riess parameter ($\boldsymbol{R} = F^2/m\hbar\omega^3$), $R \gg 1$, is satisfied. Two quasi-classical parameters arise in this problem: $\boldsymbol{R} \gg 1$ and $\boldsymbol{B} \gg 1$, $\boldsymbol{B} = (2mV_0a^2/\hbar^2)^{1/2}$ is the Born parameter. The existence of two quasi-classical parameters allows us to consider both essentially quantum systems ($\boldsymbol{B} \approx 1$) in the region $\boldsymbol{R} \gg 1$i and quasi-classical systems ($\boldsymbol{B} \gg 1$) within a framework of a unified approach.

We discuss the relation between the applicability of the KramersHenneberger approximation and the determination of the threshold of adiabatic stabilization [2]. We show that the value of the threshold field strength of adiabatic stabilization in the low-frequency region does not depend on the frequency and is defined by the characteristic atomic field strength. The results of our analysis are compared with the recent results of numerical simulations of ionization in a superatomic low-frequency field [3], and with the applicability conditions of the Kramers-Henneberger approximation obtained earlier [4].

References

1. H.A. Kramers, Les Particules Elémentaires, Report to the Eighth Solvay Conference, Brussels: Editions Stoops *(1950);* W.C. Henneberger, Phys.Rev.Lett. 21,838 (1968).
2. M. Pont and M. Gavrila, Phys. Rev.Lett ***65,*** 2362 (1990).
3. A. M. Popov, O.V. Tikhonova and E. A. Volkova, J. Phys. B: At. Mol. Opt. Phys. 32, 3331 (1999).
4. M. Gavrila and J. Z. Kaminski, Phys. Rev.Lett *52,* 613 (1984).

9th International Workshop on Laser Physics (LPHYS'2000)
Seminar: Strong-Field Phenomena
July, 2000; Bordeaux, France

The Evolution of Large Clusters in a Super-Intense Laser Field

M.B. Smirnov
Max-Born Institute, Abt. B2, Rudower Chaussee 6,
12489 Berlin, Germany, and
RSC Kurchatov Institute, 123182 Moscow, Russia
and
V.P. Krainov
Moscow Institute of Physics and Technology,
141700 Dolgoprudny, Moscow Region, Russia; e-mail: krainov@cyberax.ru

Summary

The evolution of large clusters (with number of particles > 1000) is considered when the cluster is irradiated by a super-intense ultra-short laser pulse. Simple Thomas-Fermi and Thomas-Fermi-Dirac models are developed to describe the electron distributions in both the cold and hot (with the electron temperature larger than 1 keV) clusters and cluster ions [1,2]. The cluster excitation results from the interaction of the electron subsystem with the laser pulse. In was found that the external laser field penetrates only inside the thin surface layer of the cluster. The various mechanisms of internal ionization (ejection of electrons from atoms inside the cluster) and external ionization (ejection of electrons from the cluster) are discussed [3]. The charge of producing cluster ions has been derived based on the thermal evaporation of electrons from the surface of the cluster. The increasing of the electron temperature during the laser pulse is achieved due to inverse stimulated bremsstrahlung [4]. The optical density of the cluster plasma is found to be relatively small for resonance X-ray radiation transitions of multicharged atomic ions inside the cluster. Thus, the reabsorption of photons is inefficient in the cluster plasma. The optimal conditions are analyzed for the effective absorption of the laser radiation by the large clusters.
This work was supported by a grant from the Russian Fund for Fundamental Research (Grant No. 99-02-17810).

[1] M.B. Smirnov, V.P. Krainov 1999 *JETP* **88** 1102
[2] M.B. Smirnov, V.P. Krainov 1999 *Las. Phys.* **9** 943
[3] M.B. Smirnov, V.P. Krainov 2000 *Las. Phys.* **10** N1
[4] T. Ditmire et al 1996 *Phys. Rev.* A **53** 3379

The Excitation of Vibrational States of the H_2^+ at the Tunneling Ionization of the H_2 by a Strong Laser Field

M. E. Sukharev
Fiber Optics Research Center
at the General Physics Institute of Russian Academy of Sciences
38 Vavilov str., Moscow, 117756, Russia
e-mail: maxtheor@fo.gpi.ru

Unlike atoms, the molecules have additional degrees of freedom connected with the vibrations of molecular nuclei and rotations of the molecules. As a result, the molecular energy spectrum is much more complex compared to the atomic energy spectrum. The interactions of laser radiation with molecules contain much more interesting effects than those with atoms. Franck-Condon factors determine probabilities of transitions into various excited vibrational states of molecular ions from the ground vibrational state of the neutral molecule at the ionization process [1-3]. They are derived for different molecules [4]. However, a strong laser field changes these probabilities. In the tunneling ionization of the neutral molecule the ionization rate depends exponentially on the ionization potential. Therefore this rate diminishes even at the small increasing of the ionization potential due to excitation of vibrational states of the molecular ion. The goal of our investigation is to calculate the field perturbed Franck-Condon factors for the simplest case: tunneling ionization of the neutral hydrogen molecule by a strong long wavelength laser radiation. We should also take into account in such a derivation that the effective potential curve for the ground electron state of the hydrogen molecular ion is perturbed by the laser field.

The excitation of the various vibrational states of the hydrogen molecular ion at the tunneling ionization of the neutral hydrogen molecule by a strong laser field has been investigated within the frame of the tunneling quasi-static approach. The perturbed potential curve of the ground electron state of H_2^+ takes into account both Stark shift and the non-adiabatic Landau-Zener transitions between the ground and the first excited electron states of H_2^+. This effective potential is averaged over the laser field period. The Franck-Condon factors are derived for the transitions from the ground state of the nelutral hydrogen molecule to the variousvibrational states of the hydrogen molecular ion. The rates for the transitions into these states are determined as a product of the Franck-Condon factors and of the corresponding tunneling rates. The latter decrease with the vibrational quantum number. It is found that the maximum effective excitation rates are shifted to the greater vibrational quantum numbers at the increasing of the field intensity

References

1. Ilkov F. A., Walsh T. D. G., Turgeon S., and Chin S. L. 1995 *Phys. Rev. A* **51**, R2695.
2. Ilkov F . A., Walsh T. D. G., Turgeon S., and Chin S. L. 1995 *Chem. Phys. Lett.* **247**, 1.
3. Walsh T. D. G., Ilkov F. A., Chin S. L., Chateauneuf F., Nguen-Dang T. T., Chelkowski S., Bandrauk A. D., and Atabek O. 1998 *Phys. Rev. A* **58**, 3922.
4. Slater J. C., 1963 *Electronic Structure of Molecules* (McGraw-Hill: New York).

STIMULATED HYPER-RAMAN SCATTERING EFFECT AT INFLUENCE OF LASER RADIATION ON Ba ATOMS

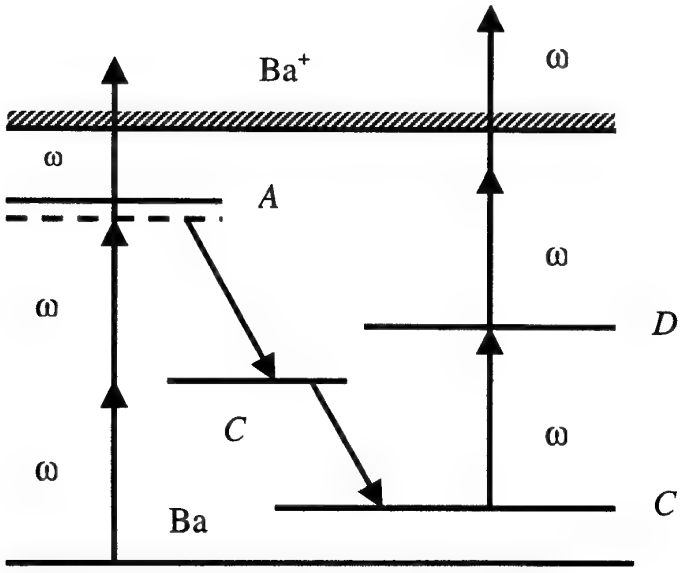
V.V.Suran, I.I.Bondar

Physical Department, Uzhgorod State University,
Voloshin str.54, 294000, Uzhgorod, Ukraine
Tel.(031-22) 361-87, Fax.(031-22) 323-39,
e-mail: QEL@ iss.univ.uzhgorod.ua.

The effect of hyper-Raman scattering of light on the atoms which leads to formation of Ba atoms in excited states at multiphoton ionization of these atoms was discovered for the first time. Scheme of this process is given in Fig. The process of hyper-Raman scattering was discovered while studing the dependence of Ba^+ ions yield (N^+) on frequency of laser radiation (ω=14800-18700 cm^{-1}).

In the N^+ (ω) dependence for Ba^+ ions we observed resonances at frequencies 14935, 14975, 15415, 16360, 16485, 16675, 16740, 16920, 17220 cm^{-1}. Note, that maxima manifest as at linear as well as at circular polarization of radiation and at field strength $\varepsilon = 5\times10^4$ V/cm. Widths of these maxima are change from 5 to 30 cm^{-1}.

These maxima are caused by realization of one-photon excitation of $5d6p\ ^3D^0_{1,2}$, $5d6p\ ^3P^0_{1,2}$, $5d6p\ ^1F^0_3$ states (*D*-states) from metastable $6s5d\ ^3D_{1,2,3}$, $6s5d\ ^1D_2$ states (*C*-states). Characteristic peculiarity of these maxima is that they are located in the vicinity of frequencies of two-photon excitation of $6s6d\ ^1D_2$, $6s6d\ ^3D_3$, $5d7s\ ^1D_3$, $5d7s\ ^3D_2$ and $6p_2\ ^1S_0$ states (*A*-states). Excitation of *B*-states proceeds in result of hyper-Raman scattering of light on *A*-states. As *B*-states could be $6s6p\ ^1P^0_1$ and $6s6p\ ^3P^0_1$ states or that *D*-states which do not cause resonant maximum in the yield of Ba^+ at this frequency.



Atom above-threshold ionization with two-component field: Applications for high-order harmonic generation with frequency selection and for femtosecond streak camera

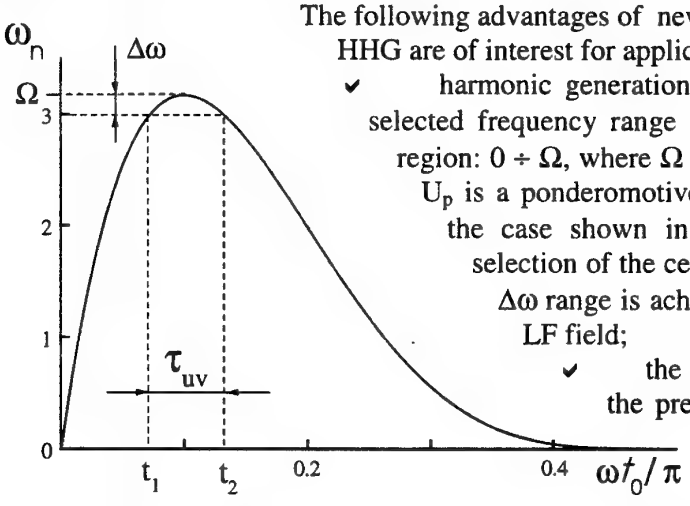
V.D.Taranukhin

Physics Department, Moscow State University, Vorob'evy gory, Moscow 119899, Russia
tvd@ssf.phys.msu.su

A new scheme of high-order harmonic generation (HHG) with two-component pump field is presented. It is proposed that the first component of a pump field is a low-frequency (LF) radiation, for example CO_2 laser, which is strong enough for HHG (~ 5×10^{13} W/cm^2). However, LF radiation must not ionize the atoms by itself. Another pump component should be an ultrashort UV pulse (τ_{uv} ~ 1-3 fs) which can resonantly ionize the atoms. Such pulses ($\hbar\omega_{uv}$ ~ 10 eV) are effectively obtained in current HHG experiments.

If UV pulses are precisely synchronized in time with the LF radiation, then photoelectrons (released by UV pulses) gain the kinetic energy in the continuum (due to LF field) which essentially depends on the phase ωt_0 of LF field (like in the femtosecond streak camera [1]). So, the LF radiation serves for the acceleration of the photoelectrons and returning them to the vicinity of the parent ion where they can recombine. The frequency of high-order harmonics ω_n generated at this recombination also depends on the phase ωt_0 (see Fig. where the case of CO_2 radiation with $\omega t_0 = \pi/10$ (from the crest of LF field) and UV pulse with τ_{uv} = 1 fs is shown).

We develop the description of atom above-threshold two-color ionization corresponding to the above scheme. The first step of such an ionization is equivalent to the one-photon resonant ionization with account for the decrease of atom ionization potential in the presence of dc (LF) field. A doublet structure of photoelectron wavepacket is typical for such an ionization. After the transient step, the evolution of wavepacket (which keeps the doublet structure) is well described by a classical trajectory of the wavepacket center.



The following advantages of new (two-component) scheme of HHG are of interest for applications:

- harmonic generation occurs only in the narrow and selected frequency range $\Delta\omega$ (not in the whole "plateau" region: $0 \div \Omega$, where $\Omega \approx 3.17\ U_p$ is a cut-off frequency, U_p is a ponderomotive potential of LF radiation). For the case shown in the Fig., $\Delta\omega \approx 0.05\ \Omega$. The selection of the central frequency of high harmonic $\Delta\omega$ range is achieved by tuning the amplitude of LF field;
- the number of the photoelectrons in the present HHG scheme is essentially less than in the ordinary scheme: the electrons are released from the atom only during the small part (~ τ_{uv}) of the optical cycle of LF field. This prevents the ionization saturation and improves the phase matching condition for HHG.

This work was supported by RFBR (grant 00-02-17533).

1. E.Constant, V.D.Taranukhin, A.Stolow, and P.B.Corkum. Phys. Rev., A**56**, 3870 (1997).

Ultrafast-Pulse Metrology as a Probe of Femtosecond Plasma Dynamics

F. A. Weihe, Ph. Balcou, S. Sebban, G. Grillon, R. Haroutunian, F. Augé, G. Chériaux
Laboratoire d'Optique Appliquée-ENSTA
Ecole Polytechnique, Chemin de la Hunière
91761 Palaiseau Cedex
France
Tél: 33-1 69 31 98 71 Fax : 33-1 69 31 99 96 Email: weihe@enstay.ensta.fr

When a short, intense pulse is focused in a gaseous medium, nonlinear effects such as ionization and the optical Kerr effect result in a refractive index in the target which varies with both space and time. As a result, the amount of phase accumulated will vary across the pulse's temporal and spacial profile.

When the pulse exits the medium, its temporal and spacial structure contains information about the time evolution of the free electron density, as well as about other pulse-induced changes in the refractive index of the target. This usually results in a blue-shift or blue-broadening of the pulse spectrum[1].

In contrast, we have used the SPIDER[2] technique to perform a complete measurement of the pulse shape of 35fs, 800nm pulses after they have passed through a focus in a rare gas target. Target densities were varied from 0 torr to 30 torr, and peak focused intensities were varied from about 10^{14} to 5×10^{14} W/cm^2. We have observed changes in the spectrum $I(\omega)$, pulse shape $I(t)$, and temporal phase $\phi(t)$, which depend on the target density and pulse energy.

Using the vacuum-propagation pulse shape as a baseline, we have able to observe the onset and saturation of ionization during the rising edge of the pulse, and resonant interactions between the pulse and the plasma.

We believe these are the first direct, time-resolved measurements of ionization rates within the evolution of an ultrashort pulse. The ionization rate during the rising edge of an ultrafast pulse has important consequences for high-order harmonic generation, affecting the efficiency of HHG and the location of the cut-off [3], and phase-matching[4], and these measurements can provide a direct test of current theories.

Under certain conditions we have also observed modulations in the pulse's spectrum and shape, which appear to be closely associated with the onset of a self-focusing or self-columnation of the beam. The modulation frequency could be related to a Raman modulational instability[5].

[1] Wood et. al., Opt. Lett. **13** 984 (1988)

[2] C.Dorrer, Opt. Lett. **24** 1532 (1999).

[3] Z.Chang et. al., Phys. Rev. Lett. **79** 2967 (1997).

[4] Bouhal et. al., Phys. Rev. A **58** 389 (1998).

[5] W.B.Mori, IEEE J. Q. E. **33** 1942 (1997).

Physics of correlated double ionization of Helium in strong laser fields

Gennady L. Yudin and Misha Yu. Ivanov

Femtosecond Program, Steacie Institute for Molecular Sciences,
National Research Council of Canada, 100 Sussex Drive,
Ottawa, Ontario, K1A 0R6 Canada

We revisit the recollision model of correlated multiphoton double ionization of atoms in strong laser fields. We develop consistent quantitative theory that yields excellent agreement with experiment on Helium, and describe a set of important physical effects responsible for the surprisingly high yield of doubly-charged ions. All these effects originate from the key role of the Coulomb potential and its interplay with the laser field. In addition to the Coulomb focusing of the oscillating trajectories onto the ionic core, other important effects include transient trapping of the electrons in the vicinity of the ionic core, the creation of high-velocity electrons at all phases of the laser field, and dominant role of collisional excitation of the parent ion followed by laser-assisted ionization.

High Order Harmonic Generation Efficiency in n-type Silicon and InP

M. Zarcone, D. Persano Adorno, G. Ferrante

Istituto Nazionale di Fisica della Materia,
Dipartimento di Fisica e Tecnologie Relative,Viale delle Scienze,
90128 Palermo, Italy
e-mail zarcone@unipa.it
fax (39) 091236306

Harmonic generation in semiconductors is of interest in its own right, but it may prove useful also for the general understanding of the several features of this highly nonlinear process. In the far-infrared region, linear as well nonlinear optical properties are mainly determined by the motion of the free carriers in the field of the incident wave. Numerous physical mechanisms may potentially act to produce harmonics generation, and the elucidation of their separate influence may well yield interesting informations for the general understanding of several features of the highly nonlinear process.

We have studied the efficiency of harmonic generation in a n-type bulk Si and InP using a Monte Carlo (MC) simulation for the motion of the free carriers in the external electromagnetic field combined with the nonlinear electrodynamic equations. From MC simulation we obtain the time dependent drift velocity; taking the Fourier coefficients of the drift velocity we calculate the dependence of the nonlinear dielectric susceptibility χ_n as function of the electric field amplitude; solving the nonlinear wave equation at the n-th harmonic frequency we get the amplitude and intensity of the n-th harmonics. The electron collision mechanism included are: collision with impurity, collisions with optical phonons polar and non polar, collisions with acoustic phonons.

We report on: 1) the efficiency of the harmonics generation as a function of the intensity of the fundamental field; 2) the efficiency of the harmonics generation as a function of the lattice temperature; 3) the influence of the different scattering mechanism on the efficiency of the harmonics and their relative importance for the two samples Si and InP. The efficiency of the harmonics is very high going from 2 10^{-2} for the 3rd harmonics to 2 10 $^{-6}$ for the 13th one. Extensive calculations yield a lot of new information on the mechanisms of harmonics generation in radiation semiconductors interaction

Physics of Cold Atoms

Poster Session

Chairs: C. Salomon (France), W.P. Schleich (Germany), V.P. Yakovlev (Russia) **Session 3.P**

3.1. O.N. Prudnikov, A.V. Taichenachev, A.M. Tumaikin, V.I. Yudin (Novosibirsk, Russia)
Light force on atom in a resonant field formed by elliptically polarized waves

3.2. S. Varro (Budapest, Hungary)
Regular phase states for a probability operator measure

3.3. M.P. Kondrashin, V.P. Yakovlev (Moscow, Russia)
Bipotential motion and anomalous transport in optical lattices

3.4. A.V. Tarasishin, S.A. Magnitskii, A.M. Zheltikov (Moscow, Russia)
Laser guiding of atoms in photonic crystals

3.5. S. Maniscalco, A. Messina, A. Napoli (Palermo, Italy)
X-Y correlation effects in the dynamics of a bidimensionally trapped ion

Light force on atom in a resonant field formed by elliptically polarized waves

O.N. Prudnikov, A.V. Taichenachev, A.M. Tumaikin and V.I. Yudin
Novosibirsk State University, Novosibirsk 630090, Russia
phone: (3832) 397234; fax: (3832) 397101; e-mail: llf@admin.nsu.ru

In almost all papers on polarization-gradient laser cooling a resonant light field is formed by running waves with pure (linear or circular) polarizations. However, as it can be seen from symmetries of the light force, there exist features connected with the ellipticity of waves. Previously, such features have been analyzed by us in the case of a standing wave with given elliptical polarization [1].

In the present paper we study the light forces in a general 1D field formed by counterpropagating waves with elliptical polarizations $\mathbf{e}_1$ and $\mathbf{e}_2$. The complex unit vectors govern the orientation of ellipses and the ellipticity parameters ε_1 and ε_2 defined by $\cos(2\varepsilon_i) = (\mathbf{e}_i \cdot \mathbf{e}_i)$. The resulting field, in general, has all possible gradients, i.e. the phase, intensity, ellipticity and orientation of the ellipse are spatially non-uniform. Using the steady-state density matrix for atoms with the ground-level angular momentum $J_g = 1/2$, we find analytical expressions for the light force and diffusion coefficient, which govern the translational dynamics of atoms in the quasiclassical approximation. Here we want to consider two classes of symmetrical field configurations, where the most interesting consequences arise.

First, $\varepsilon - \theta - \varepsilon$ configuration is formed by waves with the same intensity and ellipticity, but with differently oriented polarization ellipses (θ denotes an angle between them). In this case from the symmetry of the density matrix with respect to rotations, space-inversion and time-inversion one can deduce for the light force averaged over spatial period the following relationship $F(v,\delta) = -F(v,-\delta)$ (v is the velocity and δ is the detuning). Note that for all 1D configurations formed by waves with linear or circular polarizations we have $F(v,\delta) = F(-v,-\delta)$. This means that for atom in the rest $v = 0$ the dipole force can be rectified in a monochromatic field of two parallel waves, if $\varepsilon \neq 0, \pm\pi/4$ and $\theta \neq 0, \pm\pi/2$. Our calculations confirm this statement. We show that the averaged dipole force can be as much as $0.1\hbar k\delta$ for the Rabi frequency of order of δ.

Second, $\varepsilon - \theta - (-\varepsilon)$ configuration is similar to the previous one, but the electric field rotates in opposite direction along the polarization ellipses. Here the symmetry gives $F(v,\delta) = -F(-v,\delta)$, i.e. the averaged force is odd in the velocity, but the detuning dependence can be arbitrary. In particular, the friction force $F_{fr} = \alpha(\delta)v$ can contain odd as well as even powers of δ. Again, it is confirmed by explicit calculations for an atom with $J_g = 1/2$. For example, if the excited-level angular momentum $J_e = 1/2$ in the low-saturation limit we obtain

$$\alpha = -\frac{3\cos^2(2\varepsilon)\sin(\theta)[2\delta\sin(\theta)/\gamma + \sin(2\varepsilon)\cos(\theta)]}{2(1-\cos^2(2\varepsilon)\cos^2(2\theta))^{3/2}},$$

where γ is the radiative-decay constant of the excited level. One can see that α does not vanish in the exact resonance $\delta = 0$, if $\varepsilon \neq 0, \pm\pi/4$ and $\theta \neq 0, \pm\pi/2$, when its sign is determined by the sign of the product $-\sin(2\varepsilon)\cos(\theta)$ (i.e. by the field geometry). Similarly, we find that diffusion coefficient contains terms with the odd dependence on the detuning. These terms arise due to mixing of dipole and scattering (spontaneous pressure) forces.

1. O.N. Prudnikov, A.V. Taichenachev, A.M. Tumaikin, V.I. Yudin , JETP, **88**, 433 (1999).

Regular Phase States for a Probability Operator Measure

Sándor Varró
Research Institute for Solid State Physics and Optics
Hungarian Academy of Sciences
H - 1525 Budapest, P.O.Box 49, Hungary
phone : ++ (36-1) 3 959 220 , fax : ++ (36-1) 3 959 286
e - mail : varro@sunserv.kfki.hu

By using a variant of the polar decomposition of the photon absorption operator proposed by Aharonov et al. [1], namely $A = F\sqrt{N+\nu}$, a new formalism is developed to handle the problem of quantal phase of a mode of the radiation field. Regular phase states are introduced which are normalized eigenstates of the contraction operator F. They are in fact pure negative binomial states with exponent $-(\nu+1)$, where ν is an arbitrary positive parameter. These states form a complete set on the Hilbert space of the mode in contrast to the normalizable eigenstates of the well known exponential phase operator E introduced by London [2] long ago, and used later by Susskind and Glogower [3]. An analogue of the Garrison and Wong [4] phase operator is defined as an uniformly convergent series of powers of F and its adjoint. It is shown that the antinormally ordered exponential phase operator associated to this new phase operator reduces through F to E in the $\nu \to 0$ limit. This behaviour is slightly similar to the correspondence [6], [7] between the Pegg and Barnett [5] and the Susskind and Glogower [3] description of phase-related quantities, exept for in our formalism all the operator series are *convergent in norm* rather than in the week sense .

With the help of the regular phase state basis a new probability operator measure is defined on the $[0,2\pi)$ interval, and cosine and sine operators are introduced which satisfy the usual c-number trigonometric relations. A possible application of our formalism to interpret the experimental results by Noh, Fougeres and Mandel [8] on phase dispersion is outlined.

The present work has been supported by the National Science Foundation of Hungary under contract number OTKA T032375.

References

[1] Y Aharonov, E C Lerner, H M Huang and J M Knight: J. Math. Phys.,**14**,746-756(1973)
[2] F London : Z. f. Phys., **40**,139-210 (1927)
[3] L Susskind and J Glogower : Physics, **1**, 49-61 (1964)
[4] J C Garrison and J Wong : J. Math. Phys., **11**, 2242-2249 (1970)
[5] D T Pegg and S M Barnett : Phys. Rev., **A39**, 1665-1675 (1989)
[6] A Luks and V Perinova : Physica Scripta, **T48**, 94-99 (1993)
[7] J Vaccaro and Y Ben-Aryeh : Opt. Comm., **113**, 427-432 (1995)
[8] J W Noh, A Fougeres and L Mandel : Phys. Rev., **A45**, 424-442 (1992)

Bipotential motion and anomalous transport in optical lattices.

M.P. Kondrashin and V.P. Yakovlev
Moscow State Engineering Physics Institute,
Kashirskoe shosse 31, 115409 Moscow, Russia
Tel: +7(095)323-97-77, Fax:+7(095)324-21-11
e-mail: michael@theor.mephi.ru, valery.yakovlev@physik.uni-ulm.de.

Atomic motion in optical lattices [1,2] shows anomalous transport properties when the optical potential depth U becomes smaller than some critical value [3]. Anomalous dynamics was recently demonstrated in the experiment [4]. We present an analytical treatment of atomic motion in a one-dimensional optical lattice for ground state atoms using the standard scheme [1] based on the atomic transition 1/2-3/2 driven by a lin _|_ lin configuration of two counterpropagating laser waves.

We identify three velocity domains: (i) $kv \ll \Gamma$ (Γ is an effective relaxation rate), (ii) $\Gamma \leq kv \leq U$ and (iii) $kv \gg U/\hbar$, with an essentially different character of the atomic motion governed by different kinetic equations. The motion of slow (i) atoms is governed by the Fokker-Plank equation with spatially modulated kinetic coefficients. We show that the spatially homogeneous F-P equation used in Refs. [2,3] is valid only in the domain (iii), that is for asymptotically large velocities, when we are allowed to neglect spatial harmonics of the distribution function.

The most interesting behavior takes place in the intermediate velocity domain (ii). Here the atomic motion has an essentially bipotential character and can not be described by the F-P type equation. We show that the atoms with intermediate velocities are responsible for the anomalous spatial diffusion.

References

[1] J. Dalibard and C. Cohen-Tannoudji, J. Opt. Soc. Am. B 6, 2023 (1989)
[2] Y. Castin, J. Dalibard, C. Cohen-Tannoudji: In "Light Induced Kinetic Effects on Atoms, Ions and Molecules", eds. By L. Moi, S. Gozzini, C. Gabbanini, A. Arimondo, F. Strumia (ETD Editrice, Pisa 1991)
[3] S. Marksteiner, K. Ellinger, P.Zoller. Phys. Rev. A 53, 3409 (1996)
[4] H. Katori, S. Schlipf, H. Walter, Phys. Rev. Lett. 79, 2221 (1997)

Laser Guiding of Atoms in Photonic Crystals

A.V. Tarasishin, S.A. Magnitskii, and A.M. Zheltikov

International Laser Center, Physics Faculty, Moscow State Univ., Moscow, 119899 Russia

The abilities of photonic crystals to stop and localize light are well known [1]. They are widely discussed now in the context of different problems of laser physics [2]. This paper focuses on yet another remarkable property of photonic crystals that has not been fully appreciated so far : the ability to guide and manipulate atoms.

Our analysis is based on the finite-difference time-domain simulation of light-field distribution in a defect mode of a two-dimensional photonic crystal with a defect of a photonic-crystal lattice. Such structures allow the light field to be localized in an area with a subwavelength size [3]. With an appropriate geometry of the defect in the photonic-crystal lattice, a potential permitting the laser guiding of atoms with can be produced. The field distribution in a 2D photonic crystal allows the guiding of atoms, similar to hollow-core fibers [4], with blue-detuned radiation. The main advantages of such an atom guide would stem from the fact that the light field in such a structure may decrease by nearly five orders of magnitude on the subwavelength spatial scale, providing a very high localization degree of atoms, which are pushed to the center of the defect due to the dipole force. Another important advantage is that the rate of spontaneous emission can be greatly reduced in such an atom guide if the emission wavelength falls within the band gap of the photonic crystal. Along with some beautiful physics, the above-described photonic-crystal atomic guides show much promise for many problems of atomic optics, offering several important advantages over hollow fibers.

References

1. E. Yablonovitch, J. Opt. Soc. Am. B 10, 283 (1993).
2. J. Joannopoulos, R. Meade, and J. Winn Photonic Crystals (Princeton: Princeton Univ., 1995).
3. A.M. Zheltikov, S.A. Magnitskii, and A.V. Tarasishin, JETP Lett. 70, 323 (1999); S.A. Magnitskii, A.V. Tarasishin, and A.M. Zheltikov, Appl. Phys. B 69, 497 (1999).
4. M.A. Ol'shanii, Yu.B. Ovchinnikov, and V.S. Letokhov, Opt. Commun. 98, 77 (1993).

TITLE: x-y correlation effects in the dynamics of a bidimensionally trapped ion

AUTHORS: S. Maniscalco, A. Messina and A.Napoli

AFFILIATION: Dipartimento di Scienze Fisiche ed Astronomiche dell'Universita' di Palermo

ADDRESSES: Dipartimento di Scienze Fisiche ed Astronomiche, via Archirafi 35, 90123 Palermo, Italy

TELEPHONE/FAX: ++390916234243

EMAIL: messina@fisica.unipa.it

ABSTRACT:
Over the last few years there have been realised experiments on single trapped ions, cooled down to their zero-point vibrational energy. The interest toward such systems is that we have at our disposal almost ideal conditions to test fundamental aspects of quantum mechanics.
In our work the physical system under scrutiny is an ion, isotropically confined in the radial plane of a miniaturised Paul trap, irradiated with two properly configured laser beams.
We investigate the quantum dynamics of this system focussing in particular our attention on the quantum correlation get established between the two different spatial degrees of freedom of the oscillator. The physical origin of this correlation is clearly traced back to the coupling between the electronic and vibrational subsystems driven by the two laser beams.
Our results concern the quantum covariance C(X,Y) of the dynamical variables X and Y, as well as that of their conjugate momenta Px and Py, C(Px,Py).
We analytically demonstrate that, preparing the ion in an easily realisable initial state, the temporal evolution of C(X,Y) and C(Px,Py) exhibits oscillations between +1 and -1. This means that the system executes periodical transitions from conditions of maximum correlation to conditions of maximum anticorrelation. Thus we are legitimate to state that studying the quantities C(X,Y) and C(Px,Py) helps to shed light on the occurrence of nonclassical behaviour in the time evolution of our system.
Finally the possibility of revealing experimentally these correlation effects is discussed proposing a measurement procedure based on the detection of the vibrational energy of the system.

Physics of Lasers

Poster Session

Chair: G. Bufetova (Russia) **Session 4.P**

4.1. A.V. Kir'yanov, V. Aboites (Leon, Mexico), I.V. Mel'nikov (Moscow, Russia)
Relaxation Oscillations and Polarisation Mode-Locking in a Solid State Laser Containing a Saturable Polariser

A.V.Kir'yanov[1], V.Aboites[1]

I.V.Mel'nikov[2]

[1] Centro de Investigaciones en Optica A.C., Apartado Postal 948,
Leon 37000, GTO, MEXICO
Fax: (52) 47-175000, E'mail: *kiryanov@foton.cio.mx*

[2] General Physics Institute of the RAS,
Vavilov Str., 38, Moscow 117942, RUSSIA

Relaxation Oscillations and Polarisation Mode-Locking in a Solid State Laser Containing a Saturable Polariser

ABSTRACT

The relaxation oscillations are treated both analytically and numerically for a solid-state laser containing an intracavity saturable polarizer. The transition from stable cw operation to unstable relaxation oscillations is found to depend on pump power and the polarizer orientation. The conditions for polarisation mode-locking establishing in the laser are also analysed. The model is applied to explain relaxation oscillations and the quasi-mode-locking regime in a YAG:Nd^{3+} laser containing a saturable absorber on a YAG:Cr^{4+} crystal.

Laser Methods in Medicine and Biology

Poster Session

Chair: S. Gonchukov (Russia) Session 5.P

5.1. A. Chistyakov (Moscow, Russia)
Laser induced luminescence for detecting of biochemical combination traces on the surface

5.2. S. Gonchukov, M. Darvin, A. Gonchukov (Moscow, Russia)
Laser as a detector of biological activity

5.3. T. Fedorova, E. Kondrakhina, T. Sotnikova (Moscow, Russia)
Low-energy lasers in pneumonia treatment

5.4. A. Ivanov, M. Alfimov, A. Podshivalov, A. Zheltikov (Moscow, Russia)
An all-solid-state sub-40-fs self-starting Cr^{4+}: forsterite laser broadly tunable within the therapeutic window range for high-resolution coherence-domain and nonlinear-optical biomedical applications

5.5. E. Koultchavenia (Novosibirsk, Russia)
Some mechanisms of low-level laser therapy for nephrotuberculosis

5.6. V. Oshurko, Yu. Bykovsky, A. Karpiouk, A. Melekhov (Moscow, Russia)
Laser photoacoustic technique for water control

5.7. D. Rogatkin, V. Svirin, V. Tchernyi (Moscow, Russia)
The laser noninvasive complex diagnostic technique as a new branch of clinical diagnostics of the next century

5.8. E. Stranadko, A. Obukhov, U. Koraboyev (Moscow, Russia)
Concentrational quenching of photochemical bactericidal activity and triplet mechanisms of deactivation of excitation

5.9. A. Stratonnikov, V. Loschenov (Moscow, Russia)
Influence of laser irradiation on hemoglobin oxygen saturation and blood volume in skin

5.10. A. Oraevsky (Galveston, USA)
Cancer detection and diagnosis with opto-acoustic tomography

5.11. A. Kunin, Y. Ippolitov, M. Soibelmann, E. Podolskaya, B. Shumilovitch, S. Kazmina (Voronezh, Russia)
The effectiveness of using low intensive laser irradiation for treatment and prophylaxis of teeth, parodontium and oral mucosa diseases

Laser induced luminescence for detecting of biochemical combination traces on the surface

A.A.Chistyakov

Moscow State Engineering Physics Institute

31, Kashirskoe shosse, Moscow, Russia

The investigations and tests of biochemical compounds low contents on the surface is necessary for noninvasive illness diognostics, legal medicine, crime and other. For these aims the laser luminescence methods are very informative.

The unit with the excitation of luminescence tunable dye laser on the frequences mixture and multiplication has been developed. It has the wide tunable range 266-700nm. The investigations may be carried out in the temperature region 77 - 300K. Luminescence was detected both in the analog mode and in the mode of photon counting. We can to detect the luminescence imadges.

The objects of study was: dye molecules, amino acids, proteins and complecs bioorganic compaunds - blood, sweat on the surface.

It was shown that palm sweat contains riboflavin with high quantum yield of luminescence. The luminescence band lies between 520nm and 670nm with maximum near 550nm. It can be excite under visible laser radiation.

Using this result we can reach high contrast of luminescence images for sweat sampls on other surfaces. This effect was used for elaboration of laser methods and detectors of fingerprints without preliminary treatment.

Laser as a detector of biological activity

S. Gonchukov[1], M. Darvin[1], A. Gonchukov[2]

[(1)] Moscow State Engineering Physics Institute
Kashirskoe sh. 31, Moscow, 115409, Russia
Tel/Fax +7(095)321-7314; E-mail: gonch@mail.ru
[(2)] Central Research Institute for Skin and Venereological Diseases
3 Korolenko street, 107076, Moscow, Russia

Phase fluctuations of light that has been scattered from living medium depend on biological activity. While the biological processes decay the level of fluctuations decreases to the one of the inanimate tissue. This phenomenon can be observed as the speckle structure moving or the broadening of spectral line with the help of laser irradiation

In the present work intracavity laser refractometer in reflection and the laser with optical feedback have been developed for biological activity evaluation. The scattering radiation has an influence on both amplitude and frequency characteristics of laser detector. The sensitivity of optical phase measurement is within range of seconds. The sensitivity of scattering intensity registration is 10^{-9} in comparison with laser output. The scattering signal at a level of ten quanta can be measured.

LOW-ENERGY LASERS IN PNEUMONIA TREATMENT

T. A. Fedorova, E. N. Kondrakhina, T.I. Sotnikova
Moscow Medical Academy,
Department of Therapy, Faculty of Post-Graduate Education
Tel/Fax: +7(095)945-4732

Despite the progress in antibacterial therapy of pneumonia its treatment still remains one of the leading problems in pulmonology. Increases in resistance of bacterial flora and polyvalent allergy stimulate looking for new ways of effective medical care for patients with such disease. Low-energy laser therapy (LELT) should be regarded as one of highly promising methods.

Recent studies have shown the clinical efficacy and immunocorrective influence of LELT in various pathologies. Moreover, it turns out that laser irradiation with wavelength 0,63 μm opens up quite new possibilities in the treatment of microcirculatory disorders.

In this respect the aim of this research was to investigate LELT effect on clinical and hemorheological parameters in patients with pneumonia of various courses using several ways of irradiation. Radiation of He-Ne and IR lasers was applied. 123 patients from 19 up to 79 years old suffering pneumonia were examined. A severe course of pneumonia was revealed in 49% of patients and a moderate course - in 51%. 65 patients were diagnosed as having local pneumonia, 44 – as lobitis and 14 – as having a two-sided process. Results of examination were compared in four groups of patients. The 1st group was treated with transcutaneous irradiation together with antibacterial therapy. A combination of intravenous and then transcutaneous LELT was applied to the 2nd group. Transcutaneous epivenous irradiation of blood was conducted in the 3rd group. The patients of the 4th group received a conventional complex of medications and physiotherapy treatment. The clinical course and the outcome of pneumonia, the changes of microcirculation in conjunctival biomicroscopy, erythrocyte and platelet aggregation, as well as several plasma hemostasis indices were investigated in all patients.

The results of investigation showed the existence of an overall positive clinical effect of LELT in pneumonia. It was especially noticeable in the 2nd and 3rd groups. The patients felt better even after the first or second application of intravenous LELT in severe pneumonia cases: the temperature dropped, breathing got easier, pleural pains decreased or disappeared. Quick positive dynamics of percussible and auscultatory manifestations of pneumonia were marked. It is worth noting that neither prolonged course of the disease, nor complications were characteristic for patients with LELT but were characteristic for 16 % of patients in the 4th group. As a result, the period and the amount of antibacterial therapy were reduced .

The clinical effect of LELT was closely interconnected with the changes of hemorheological indices. The early stages of pneumonia were characterized by severe disorders of microcirculation in bulbar conjunctiva with the expansion of the process of erythrocyte aggregation to the whole parts of microcirculatory bed, including arterioles. The results of the laboratory investigation also revealed the increase of platelet and erythrocyte aggregation, the indicators of disseminated intravascular microcoagulation. The influence of LELT was characterized by restoration of normal blood circulation, by the decrease of these hemorheological disorderes, or normalization of indices (products of fibrin degradation, of platelet and erythrocyte aggregation, antithrombin III). These changes correlated with the clinical effect, were typical for patients of 2nd and 3rd groups, and outstripped the corresponding dynamics in the group of conventional treatment.

To summarize, the presented results show positive changes in clinical and hemorheological parameters of patients suffering pneumonia and thus substantiate the use LELT in the complex treatment of this disease.

An all-solid-state sub-40-fs self-starting Cr^{4+}:forsterite laser broadly tunable within the therapeutic window range for high-resolution coherence-domain and nonlinear-optical biomedical applications

A.A. Ivanov*, M.V. Alfimov*, A.A. Podshivalov, A.M. Zheltikov****

*** Center of Photochemistry, Russian Academy of Sciences, ul. Novatorov 7a, Moscow, Russia**

**** International Laser Center, Physics Faculty, Moscow State University, Vorob'evy gory, Moscow, 119899 Russia**

Medical applications of lasers is one of the most important and rapidly growing areas of modern laser physics. Since the light used to visualize the microstructure of biological tissues in optical biopsy is subject to attenuation due to absorption and scattering, much attention is currently focused on searching for optimal sources of light that would ensure the maximum penetration depth and would possess sufficient power to ensure reliable signal detection in various modes used to image biological systems. While absorption of human tissues is relatively weak within the so-called therapeutic window, attenuation due to the scattering of light makes light sources within the range of wavelengths from 1.2 to 1.3 μm especially suitable for the purposes of medical diagnostics. All these factors make femtosecond Cr^{4+}:forsterite lasers an attractive source for a broad range of medical applications. All-solid-state Cr:forsterite lasers have recently shown to be a perfect choice for high-signal-to-noise-ratio optical coherence tomography (OCT) imaging, allowing a resolution of several microns to be achieved [1].

In this paper, we present an all-solid-state sub-40-fs self-starting Cr^{4+}:forsterite laser with a wavelength tunable within the range of 1.21 – 1.29 μm adapted in its power, temporal, and spectral parameters for high-resolution OCT and nonlinear-optical tissue imaging is presented. Stable self-starting mode locking in the created laser is achieved both with and without semiconductor saturable-absorber mirrors. Intra- and extracavity chirp control of laser pulses produced by the Cr:forsterite laser allows OCT imaging with tunable resolution to be implemented, while the double-pulse regime of lasing (Fig. 1) permits time-resolved measurements on biological systems to be performed. The use of a regenerative amplifier extends the area of nonlinear-optical imaging applications of the developed laser.

This study was supported by the Russian Foundation for Basic Research.

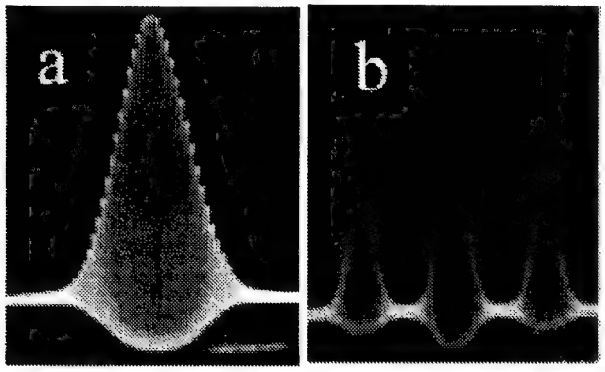


Fig. 1. (a) Single-pulse (the pulse width is 45 fs) and (b) double-pulse (the pulse width is 80 fs) modes of 100-MHz repetition rate output of the Cr:forsterite laser.

References

1. B.E. Bouma, G.J. Tearney, I.P. Bilinsky, B. Golubovic, and J.G. Fujimoto, *Opt. Lett.* **21**, 1839 (1996); G.J. Tearney, B.E. Bouma, S.A. Boppart, B. Golubovic, E.A. Swanson, and J.G. Fujimoto, *Opt. Lett.* **21**, 1408 (1996).

SOME MECHANISMS OF LOW-LEVEL LASER THERAPY FOR NEPHROTUBERCULOSIS

E.V.KOULTCHAVENIA, M.D.
Research Institute of Tuberculosis, Novosibirsk, Russian Federation
Russian Federation, 630040 Novosibirsk Kubovaya str. 107/1 ap.57
Tel. (8-383-2) - 906-930 fax (8-383-2) - 77-37-51 e-mail: nniit@sibnet.ru

The disoders of urodinamics plays main role in the pathogenesis of inflammatory diseases of kidneys including nephrotuberculosis.

69 patients were under our observation. All of them received identical course of the laser therapy: infrared laser irradiation with the power density 5,6 mWt/sm sq for 10 min., 10 procedures every day. Kidney functions were determined by Reberg-Tareev and Zimnitskiy tests and by data of radioisotopical renography.

We noted the improvemenl of the kidney functions after laser therapy. The diuresis increased an average on 76%. The summary improvement of kidney functions were in 84,2% cases. The stimulation of urine passage was noted in 79% patients. Secretory function was improved in 63, 1% patients.

The high concentration of anti-tuberculous drugs in the lesion locus also is one of the most important component in the success treatment of nephrotuberculosis.

We put the aim to increase the isoniazid concentration in kidney by low-level laser therapy.

24 patients received isoniazid (dose 0,6) before the surgical operation on the kidney. 12 patients from them in addition received laser therapy. Others were as control.

After 2 hours renal tissue was investigated. In control group the concentration of the isoniazid was 0 in 3 cases. These patients had massive pyonephrosis, renal tissue was absent. In other cases the concentration of the isoniazid was 1,7+-0,3 mkg/g on average.

The influence of the infra-red laser on the kidney promoted to increase of isoniazid concentration in the lesion locus. In this group an average concentration of the isoniazid was 18,1+-4,4 mkg/g, $P<0,05$.

Thus the laser therapy at the expense of improving of the blood microcirculation ensures to increase of the drug concentration in the lesion locus. That is one of the decisive moment for the efficiency of anti-tuberculous chemotherapy.

Besides local transcutaneous low-level laser therapy exert benefit influence on urinary system functions. Our results are convincing basis of using laser therapy in urology.

LASER PHOTOACOUSTIC DETECTION OF OIL HYDROCARBONS IN WATER EMULSIONS

V.B.Oshurko, Yu.A.Bykovsky, A.B.Karpiouk, A.P. Melekhov

Moscow Engineering Physics Institute

115409, Kashirskoye 31, dept. 25 , Moscow, Russia

Phone / fax : (095) 323 -9066

e-mail: avb @ phsearch.msk.ru

Existing methods of photoacoustic detection of hydrocarbon traces (0.1..100 ppms) in water emulsions are typically based on near-IR excitation and consequent acoustic response measurement. Indeed, in spectral region of 0.9...1.0 microns the CH vibrational overtone absorption is stronger than that of water. Nevertheless, many attempts of practical use of this method have failed. Any proportionality of acoustic response to hydrocarbon concentration may be lost with even small changes of temperature, natural water contents etc.

In present work dependences of photoacoustic reponse on temperature, water contents and light scattering have been studied in detail.

It was found that, in contrast to expectations, photoacoustic response significantly depends on light scattering in hydrocarbon emulsion. The mechanism of this effect (dealing with light intensity redistribution in scattering media) has been proposed. This mechanism has also been proved experimentally. Numeric model describing photoacoustic response dependence on temperature (including phase transition) has been built.

Using these data a novel method of hydocarbons detection for environmental control has been proposed. (another laser beam parameters). In order to establish the applicability of this method for crude oil and oil products detection (or selectivity to these substances) in water a series of photoacoustic spectra of natural waters and different oil products were obtained.

It has also been found that acoustic Fourier analysis allows one to distinguish between dissolved and emulsified hydrocarbons. As a result a reliable temperature and scattering independent method of oil hydrocarbons detection has been found.

The laser noninvasive complex diagnostic technique as a new branch of clinical diagnostics of the next century

D.A. Rogatkin, V. N. Svirin*, V.V. Tchernyi

Laboratory of Laser Medicine of Moscow Regional Research Clinical Institute "MONIKI", Russia, 129110, Moscow, Shepkina Str., 61/2.
tel:(095)971-33-00, fax:(095)315-12-84, email: laserrog@mtu-net.ru
* Russia State Research Institute "POLUS", Russia, 117342, Moscow, Vvedenskogo Str., 3, phone: (095) 333-01-77, fax (095) 333-00-33

In this report the contemporary possibilities and prospects of progress of the laser noninvasive diagnostics in medicine are discussed. The basic principles of the development and function of laser medical diagnostic systems as well as the research problems from physics to medicine, which have to be resolved during the development process, are formulated. The examples of laser medical diagnostic systems - biophotometers, flowmeters, photopletizmograph, spectrograph, etc. – and theirs techniques are shown and compared to found the common principles of how the light diagnostics runs. The results of this survey indicate a number of important conclusions. The main is that the all light methods of medical diagnostics have the main single object of investigation – the biochemical composition (BC) of biological tissues and liquids (blood, limph, etc.) and the changes of BC during the time. The next one is that the all light methods can correctly run under the principles of inverse optical task solution only. And another one is that the all methods can be united in the universal complex laser diagnostic system and technique, which can allow to obtain not only the sum of separated results but more detailed and exact medical data. So, it will be true to speak of such complex and multifunctional diagnostic technique like of the new branch of clinical diagnostics for determination in real time and noninvasive mode the BC of living tissues.

Concentrational quenching of photochemical bactericidal activity and triplet mechanisms of deactivation of excitation

E.Ph.Stranadko[1], A.E.Obukhov[2], U.M.Koraboyev[1]
1 - State Research Center for Laser Medicine, Ministry of Public Health of Russia Russia, 121165, Moscow, Studentcheskaya st., 40, e-mail: geinic@cityline.ru, phone/fax: 249-39-05, phone:187-46-29, fax: 181-24-52;
2 - Russian University of Peoples' Friendship, Russia, 117302, Moscow, Ordjonikidze st., 3, e-mail: aobukhov@sci.pfu.edu.ru, phone/fax: 952-11-86.

A series of experimental studies on lethal photosensitization of microorganisms most often met in supurative wounds (Staphylococcus aureus, Staphylococcus epidermidis, Proteus mirabilis, Esherichia coli, Pseudomonas aeruginosa). Sulphonated aluminum phthalocyanine (Photosense™) in concentrations of 20, 50 and 100 μg/ml was used as a photosensitizer for pre-irradiation incubation. Straight correlation between concentration of photosensitizer and bactericidal action of PDT was observed at the same energy density (24 J/cm^2). At higher Photosense concentration of 100 μg/ml significant (5 - 125 fold) decrease of bactericidal effect (Staphylococcus epidermidis, Staphylococcus aureus, Escherichia coli) or its absence took place (Pseudomonas aeruginosa, Proteus mirabilis) in comparison to lower concentrations (20 and 50 μg/ml).

A possibility of exciting energy transmission from long-living triplet states by inductive-resonance mechanism has been considered.

Combined analysis of three- and five-level schemes of population of excited states, quantum-chemical LCAO MO SCFCI calculations and experimental spectroscopic data of heteroaromatic compounds has been undertaken. Physical and mathematical correlation was found between energy density of the exciting light and the nature of excited state of the substance (singlet and triplet).

Coefficients for calculation of power of exciting irradiation from intensity of spectral bands of absorption and induced triplet-triplet reabsorption are proposed. Calculation of required power of the light source (laser device) including triplet reabsorption are presented.

Influence of laser irradiation on hemoglobin oxygen saturation and blood volume in skin

Alexander A. Stratonnikov and Victor B. Loschenov
Laser Biospectroscopy Lab, General Physics Institute, 38, Vavilov street, Moscow, 117942, Russia. Email: biospec@glasnet.ru

ABSTRACT
There is a lot of discussion about the influence of low intensity laser irradiation on different physiological parameters. It is very important to understand the mechanisms of low intensity laser therapy. The observing of tissue response to laser irradiation in vivo could be a strong argument to prove that low intensity laser therapy does work. Moreover, if one could observe the real time tissue response to light (laser) irradiation it would be possible to optimize the light fluence and fluence rate, irradiation wavelength etc. to increase this response and achieve maximum therapeutic effect.
Our previous work concerning the problem under question was to study the tissue auto fluorescence and its photobleaching dynamics. We observed that tissue fluorochroms are destroyed during laser irradiation in visible range including red light. We assume that these fluorochroms may be primary light absorbers to induce the chain of photochemical reactions resulting to therapeutic effects, similar to photodynamic therapy with tissue fluorochroms playing the role of exogeneous photosensitizers.
The aim of the present work was to study the response of hemoglobin oxygen saturation and relative blood volume in human skin in vivo to laser irradiation. The hemoglobin oxygen saturation and relative hemoglobin concentration in skin were evaluated from diffuse reflectance spectra in visible wavelength range. The skin spot at human hand was irradiated with laser beam and hemoglobin oxygen saturation and relative hemoglobin concentration were sampled every two second from the center of irradiated spot. It was evidently observed that hemoglobin oxygen saturation is increased after starting irradiation. It was also observed that chaotic oscillations in blood oxygen saturation observed in skin in the absence of laser irradiation became substantially smaller in the presence of laser irradiation. However these effects were observed only at sufficiently high laser fluence rates. The most probable reason is that it is due to thermal effects.

Cancer detection and diagnosis with Opto-Acoustic Tomography

Alexander A. Oraevskv*

Optoacoustic Jmaging and Spectroscopy Laboratory, Biomedical Engineering Center,
University of Texas Medical Branch, Galveston Texas 77555-0456,
tel. 1-409-772-8348, fax 1-409-772-0751, email <aaoraevs@utmb.edu>

Principles, medical applications and current status of the opto-acoustic tomography will be reviewed. Recent advances in laser opto-acoustic imaging systems (LOIS) and their application in diagnostic imaging of cancer will be presented. The basic ideas of the opto-acoustic tomography are that (1) laser pulses may be effectively used to produce acoustic sources in tissues voxels with enhanced optical absorption, and (2) ultrasonic waves can propagate in biological tissues with minimal distortion and deliver diagnostic information to the surface of tissue where they may be detected with wide-band ultrasonic transducers.

Optical contrast between various human tissues, including the contrast between normal and malignant tissues is measured in hundreds of percent and greater than any other types of contrast utilized in modem diagnostic modalities (x-ray radiography, MRI, ultrasound). The detection of laser-induced acoustic profiles within a wide range of ultrasonic frequencies (20-kHz to 200-MHz) yields images of greater contrast and sensitivity compared with images obtained utilizing ultrasound reflections from within the tissue.

For example, 2-mm breast tumors invisible in mammogram, may potentially be detected by LOIS, microscopic carcinoma may be visualized in colon and deadly melanoma metastases could be found in lymph nodes, giving physicians valuable information for designing early therapy. The duration of an ultrasonic pulse generated by a laser pulse in tumors permit accurate determination of the tumor dimensions and the arrival time of ultrasonic pulses to the detector will help to determine precisely the tumor location. Application of transducer arrays permits reconstruction of two-dimensional and three dimensional images of the organ of diagnostic interest.

Two main modifications of LOIS and their utilization in characterization of tissue heterogeneous and layered structures will be described (see Figure la, b). The first is the tomography in a forward mode, OAT-F, utilizing high sensitivity of detection (up to 3 V/bar) and where laser irradiation and ultrasonic detection performed on opposite tissue surfaces. The second is the tomography in a backward mode, OAT-B, utilizing high spatial resolution of images (up to 10 μm) and where ultrasonic signals detected at the site of laser irradiation. Results of initial clinical studies of early cancer detection with LOIS will be presented.

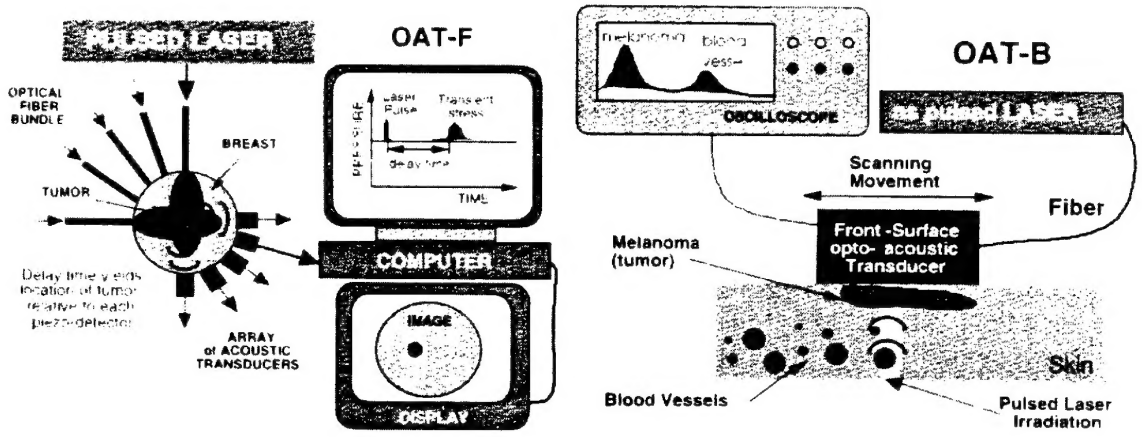


FIGURE 1. Schematic diagrams of Opto-acoustic Tomography in forward mode (OAT-F, left), and in backward mode (OAT-B, right). Typical opto-acoustic transducer for OAT-F operates in ultrasonic frequency of 30 kHz w 3 MHz, while OAT-B employs transducers in the frequency range of I MHz to 100 MHz.

THE EFFECTIVENESS OF USING LOW INTENSIVE LASER IRRADIATION FOR TREATMENT AND PROPHYLAXIS OF TEETH, PARODONTIUM AND ORAL MUCOSA DISEASES

Kunin A.A., Ippolitov Y.A., Soibelmann M., Podolskaya E.E.,

Shumilovitch B.R., Kazmina S.G.

Voronezh Medical Academy, Russia

The low intensive laser irradiation (LILI) today is effectively used in clinical practice as treating and prophylactic means. At the medical technics market there are a lot of laser therapeutic apparatus made in this country, some of them being used by us for treating and prophylactic measures. The use of the irradiation of semiconductor laser unit "Optodan" (2 min on each tooth at the second regime) and the irradiation of helium-neon laser unit ULF-01 "Yagoda" (100-200 mWt/cm^2 with a 1,5 min exposition on each tooth) together with fluorine lacquer durind 5 sessions every day or every other day for dental caries prophylaxis made it possible to liquidate completely the cariogencity of tooth layer by 87,5% and to decrease its intensity by 12,5%. LILI increases the anti-caries activity of fluorine lacquer as for the speed of the solubility of enamel by 30,8% and as for reduction of increase or dental caries by 15,2%. A high bactericidal effect upon the microflora of the caries cavity dentin is set. After the local laser irradiation with the help of the "Usor" camera disintegration of microbe associations took place in 100% cases. The use of LILI in the complex treatment of chronic generalized parodontitis of middle heaviness with the help of the "Mustang" camera (impulse power 4-6 Wt, frequency 80-150 Hz, exposure on one field of gingiva for 2 min) made it possible to remove the inflammation during 1-2 sessions. The use of 1500-3000 Hz frequency during 10 sessions led to the increase of the resistance of the vascular wall of gingiva cappilaries till 45,4 sec by Kulazhenko probe. It normalised cytograms of gingiva liquid and the capillary blood of gingiva, as well as the immunogram of the oral liquid. Combined laser treatment was used in the group of patients with afterradiation cheiltis. Medicinal treatment included application of antibacterial remedies and drugs which stimulated the repair of lips tissues. Laser therapy was formed by two stages, where we applied antiphlogistic and stimulating parameters. So, LILI must be used as part of the complex of necessary treatment and prophylaxis of stomatological diseases.

The low-level infrared laser irradiation: to a question on the mechanism of the therapeutic effect.

G.I.Klebanov[1], V.N.Christophorov[2], M.V.Kreinina[1]

[1] – Russian State Medical University, department of biophysics, Moscow
[2] – "MILTA-PKPGIT", Moscow

During laser therapy of many diseases accompanied by inflammatory processes the laser sources in red and infrared ranges of spectrum are used basically. On the bases of medical date devoted to clinical use of laser therapy may be noted that the low-level laser irradiation (LLLI) lead to improvement of microcirculation and activation of cell proliferation. In our previous reports we have been presented the concept devoted to free radical mechanism of action of LLLI in red range of spectrum. We have been suggested that the endogenous porphyrins (are known as photosensitizers and the chromophores for red LLLI) can to take part in free radical photochemical reaction leading to increase of cell functional potential (so called cell priming). At the same time, the cell mechanisms of action for infrared LLLI are not known. The influence of infrared LLLI on functional activity of blood polymorphonuclear leukocytes (PML) in vitro has been studied. The emitter of infrared LLLI "UZOR" (wavelength – 890nm, "Electronics", RF) was used. The PMLs functional activity was estimated by the method of zimozan-stimulated luminol-depended chemiluminescence. For the first time we have been found LLLI-induced PMLs priming depending on doses of infrared irradiation. Similar effects were observed in presence photosensitizer (photosense). Our further researches will be devoted to the quest of possible chromophores in infrared rage of a spectrum and to the investigation of molecular and cellular mechanisms of LLLI action.